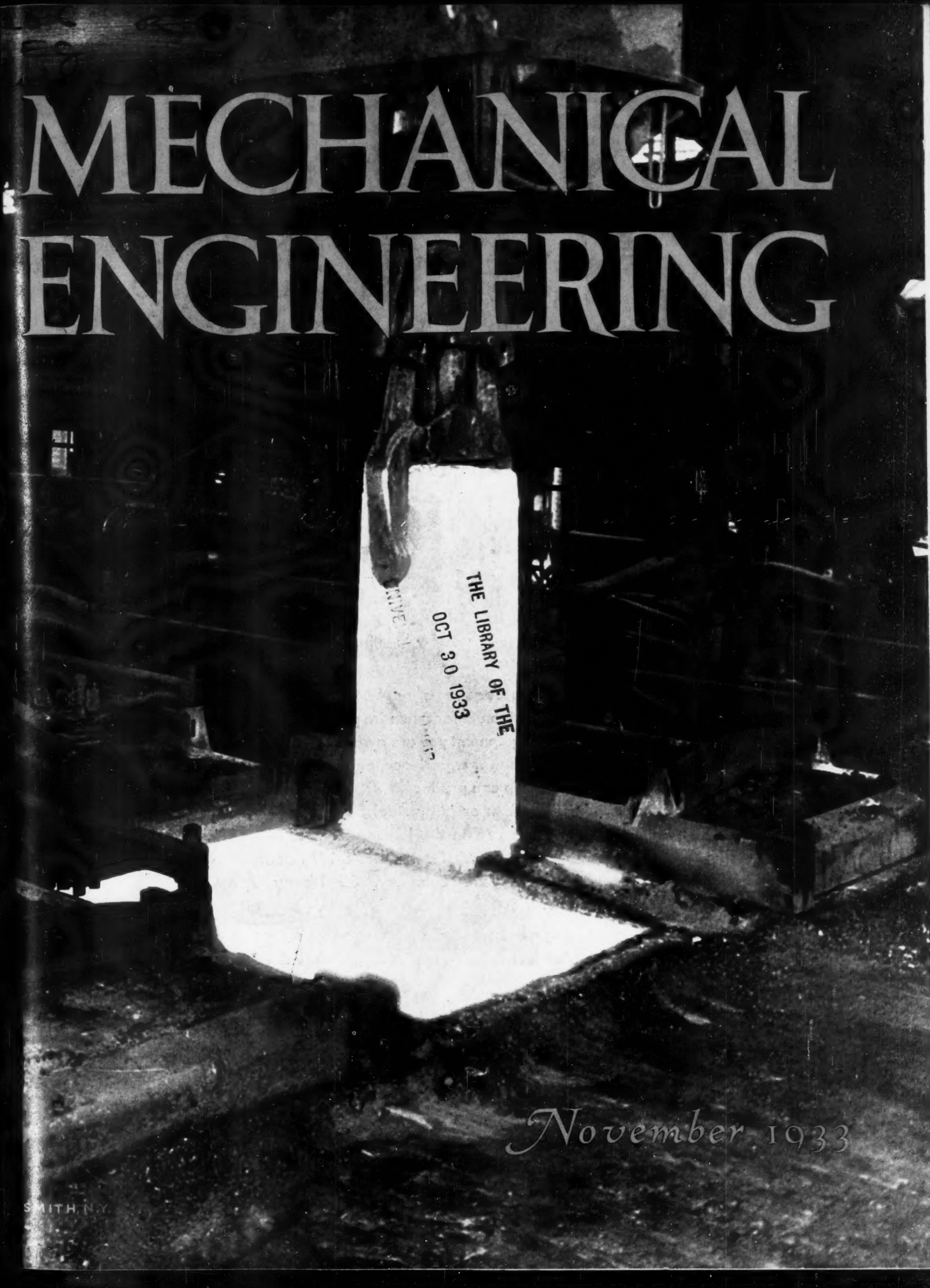
MECHANICAL ENGINEERING



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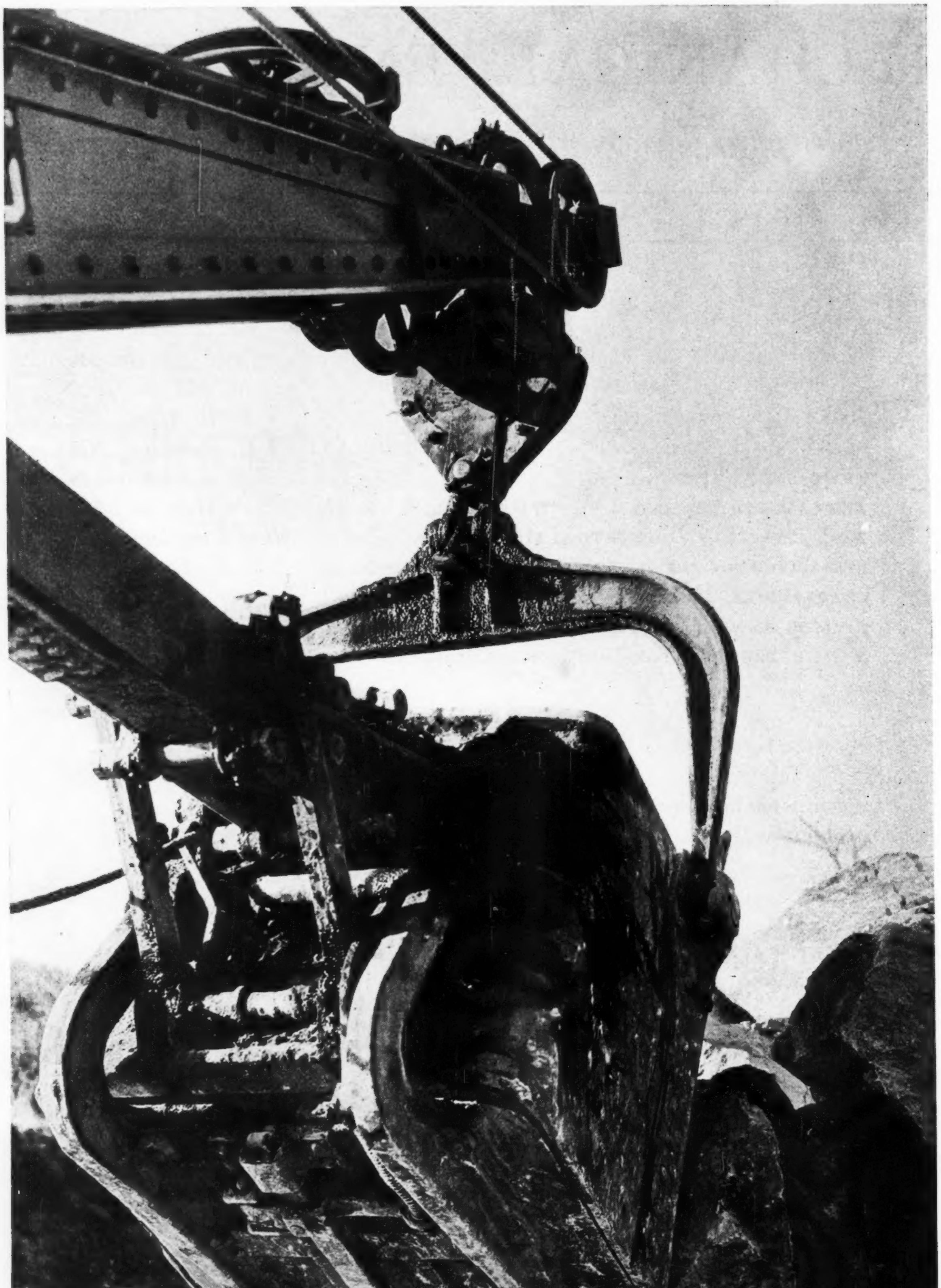

Nesmith, N. Y.

Is the Replacement Cycle in the Durable-Goods Industries Responsible for Depressions?

(Mr. McNiece's article in this issue raises this question)

Rhythmic VARIATIONS *in* INDUSTRY

By THOMAS M. McNIECE[1]

The economic characteristics of four major industries—foods, textiles, building construction, and automobiles, which absorb 75 per cent of the national income—are strikingly dissimilar. When their individual upward trends are in phase, we have a boom; when their individual downward trends are in phase, we have a depression; when all are out of phase, we have normal times. Their composite variation is always in phase with that of general business. Mr. McNiece shows that individual fluctuations in the industries producing durable goods may be initiated by replacement buying habits. Is the replacement cycle in the durable-goods industries responsible for depressions?

EACH successive generation for many years has suffered from serious economic disturbances. Nevertheless, each recurring depression finds the people unprepared for its onslaught and torn with confusion and disagreement in attempting to meet it. Contemporary accounts of past depressions are remarkably similar to those of the present.

These economic storms so seriously affect the lives of all of us that we should take more than passing interest in a better understanding of them. When the full impact of one of these disturbances strikes us, inventive genius, decreased costs, and improved quality fail to keep us out of the depths. Thus the best effort in engineering, production, and sales becomes quite ineffective until the storm has passed.

The engineering profession is concerned primarily with the determination and interpretation of facts. Upon no other basis than that of facts can rest the principles and practises involved in engineering procedure. Engineers should realize that virtually all of the theories of causation of economic surges commonly held today originated long before any records were tabulated by which they could be tested. It is only within the past few years that continuous and reasonably comparable facts on the trends of industries have become available. In the meantime, there has been a great increase in the number of people whose interest in these problems has been actively aroused. Unfortunately, however, much of the conviction so frequently expressed is not based on careful study of available facts but upon a combination of "wishful thinking" and a "follow-the-leader" spirit which may easily lead us astray.

The engineer is or should be vitally interested in the course of the industries that provide his livelihood. Upon the degree of activity in these industries depends his opportunity for profitable employment. If he examines the paths of various basic industries, he will find that both in normal and abnormal times they follow widely different courses. He will find that the hazard of unemployment in both good and bad times is far greater in some industries than in others. In his own best interest, he should seek further light on the characteristic movements of those which may provide the opportunity for his own activity. When he does this, he will find much of interest in other industries, for there is a mutual interaction among them that becomes highly important at recurring intervals.

The engineer should realize in a technical sense that the path traced by general business is but the composite average of many individual paths. He knows that in any group of forces with which he has to deal, whether it be in the design of a bridge or a machine tool, certain ones will predominate in importance. Just so, in the composite movements of business, certain component industries will assume predominating importance. How can these be determined and their importance evaluated from available facts?

ANALYSIS OF CONSUMER DEMAND

It must surely be granted that the ultimate objective of all productive effort is the satisfaction of individual needs. This applies both to consumer and producer goods. The ultimate consumer pays the full cost of all such effort. Depletion, depreciation, and obsolescence charges find their way into every commodity or service purchased by the consumer. Included in the price of a can of fruit is the purchaser's share of the depletion charges on the property that produced the ore for the can and all the machinery used in making the can and packing the fruit. Likewise, all depreciation and obsolescence charges on this equipment are included in pro rata share in this same purchase price. Even liquidation losses, where they may occur, are charges against the consumer whose savings originate in the sale of goods or services.

Since these costs are automatically prorated over consumer requirements in proportion to their importance in those requirements, some idea of their aggregate economic importance may be determined by an analysis

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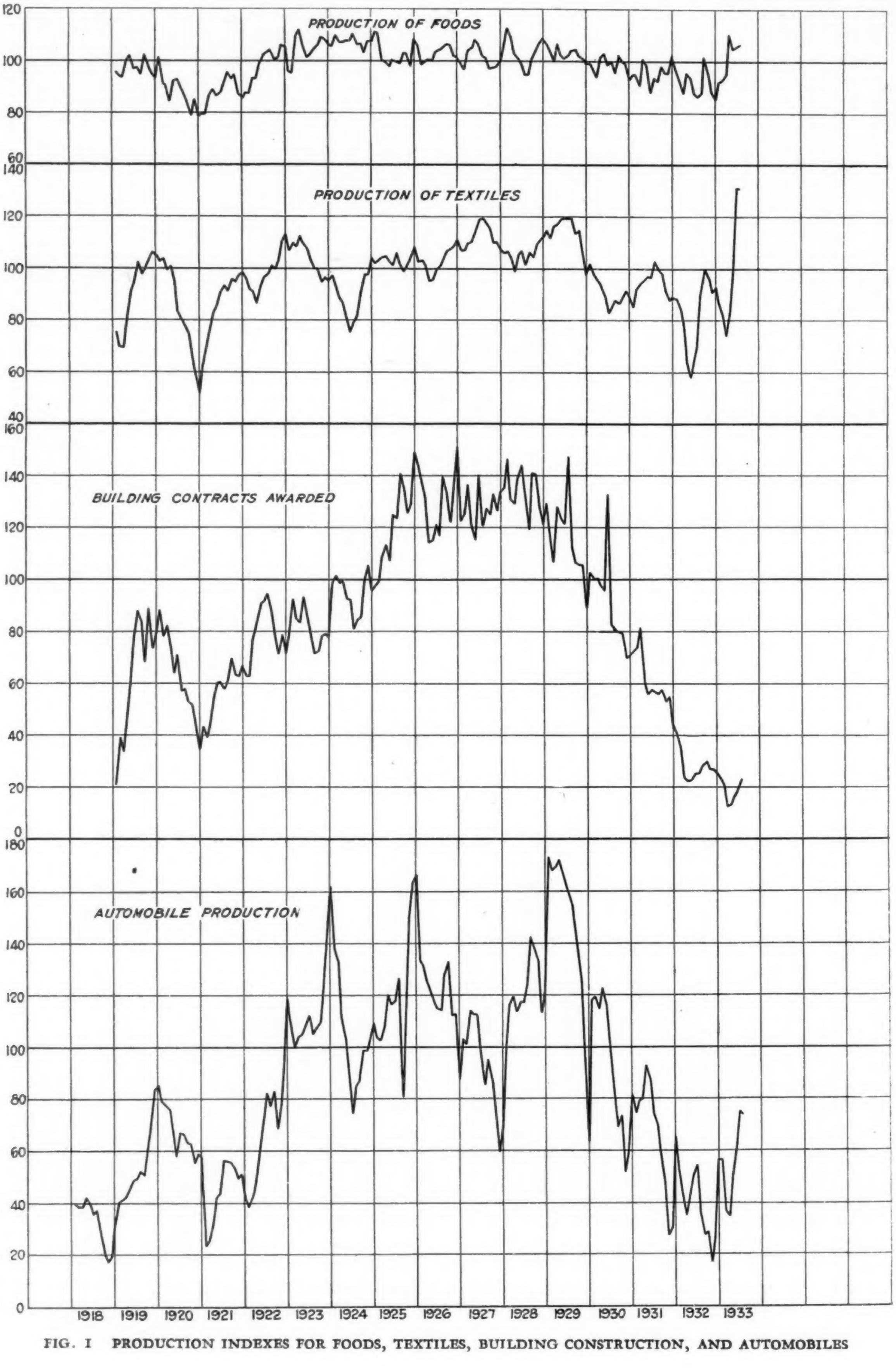


FIG. 1 PRODUCTION INDEXES FOR FOODS, TEXTILES, BUILDING CONSTRUCTION, AND AUTOMOBILES

of consumer demand. In the pursuit of human requirements, everything is subordinate to the acquisition of food, clothing, and shelter. In the United States, individualized transportation ranks next to these in desire and economic importance. Together, the products of the first three industries absorb nearly 70 per cent of individual income. When expenditure for automobiles is added to these, approximately three-quarters of individual income which pays for everything is required. This leaves but 25 per cent for all other activities, including many operating expenses, recreation, travel, savings, etc.

Any one familiar with statistical work will realize that a group of variables constituting as much as 75 per cent of the total must exert a great influence on the complete picture. This is especially true when the remaining 25 per cent is composed of such a varied and numerous list of items. A logical approach to the problem is, therefore, a study of the performance of these important industries. The composite effect of them as components of general business must be very great. A source of reliable information on the movements of these industries exists in the indexes of production published by the Federal Reserve Board at Washington, which became available after the World War. These were used to measure the activities in the food, textile, and building industries. The actual output of the motorcar industry was utilized in calculating the automobile index. In all of these industries a base of ten years, from 1920 to 1929, inclusive, was chosen as 100 per cent and the original data were converted to this base.

CHARACTERISTIC DEMAND VARIATIONS IN FOODS, TEXTILES, BUILDING, AND AUTOMOBILES

The results of these analyses are shown graphically in Fig. 1. Seasonal changes are eliminated, and the movements therefore show only annual trends and economic variations or surges. Each month's activity is shown on these charts as a percentage of the average activity in the same month for the ten-year period. If any one has assumed that the paths of these important industries have much in common, these graphs should correct the impression. A moment's glance will show that no two of them even remotely resemble each other and that none of them corresponds with the course of general business as commonly portrayed and accepted. Certain consistent tendencies in each are obvious, and these differentiate each from the others.

It will be noted that the production of foods varies in relatively irregular fashion and deviates only slightly from the average through the whole span of years. The somewhat deeper decline occurring in 1920 was caused by the sudden ending of the War and the advent of the depression, which reduced the exports of foodstuffs and also left some accumulated surplus in inventories.

The textile trend differs from that of foods in two respects. The amplitude, or degree of variation above and below normal, is much greater, and these variations exhibit a marked periodic tendency. It is obvious that a two-year surge is characteristic of the industry, with the high activity in the odd and the low in the even years. This characteristic two-year surge has continued through the current depression and right up to the present time.

Building construction shows a long climb to abnormal heights. It began a decline early in 1928 which has continued virtually to the present time. Its variation above and below the average is far greater than that of the two prior industries. The interval covered is too short to convey a comprehensive picture of this important industry. Since the principal data used in this analysis are not available prior to 1919, another series will be used to throw further light on the course followed by this industry. In Fig. 2 is shown a graph

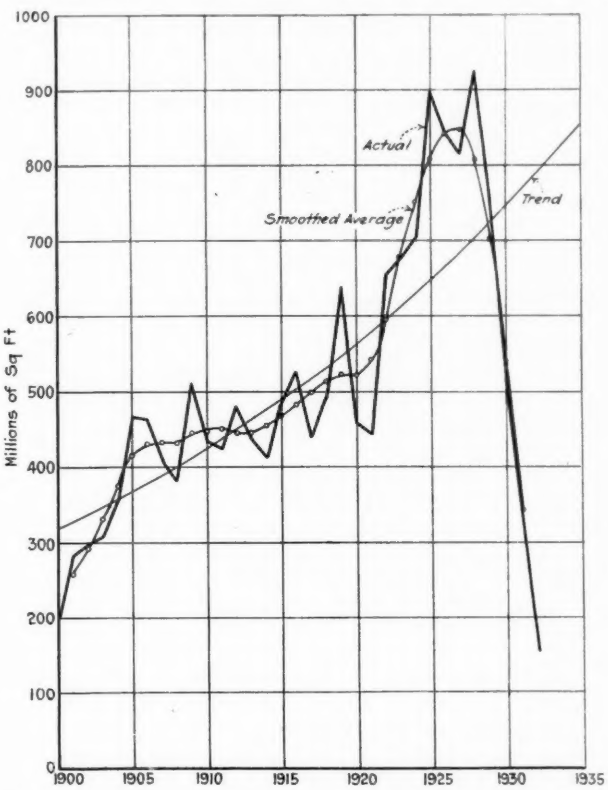


FIG. 2 BUILDING CONTRACTS AWARDED IN MILLIONS OF SQUARE FEET, 1900–1933

based on a series computed by Standard Statistics Company, Inc. This gives a measure of building activity in contracts awarded in millions of square feet per year. Study of this chart will show two periods of high activity in building since 1900. They are about 21 years apart.

Four similar peaks between 1853 and 1929 have been found by Lewis A. Maverick in real-estate activity in California. The last two are identical in timing with those shown in Fig. 2. Between 1871 and 1916, residential construction in Greater London progressed in two great waves just twenty years apart. These data all point to a series of surges in building construction at about twenty-year intervals. Careful examination of

the annual volumes indicated in Fig. 2 will show that the low points in construction activity are never less than three years apart and are very commonly at three-year intervals. The only time these periods have been longer than three years is when business was entering or emerging from some serious business depression. Mr. Maverick found this three-year surge continuing throughout the period from 1853 to 1929. There are absolutely no data in common between the two series mentioned and yet the same characteristics are found. In brief, these may be described as a series of waves about twenty years apart on the top of which is imposed a three-year ripple.

In Fig. 1 is shown the performance of the automobile industry. This is typified by wide fluctuations above and below normal that are both greater and more frequent than those in building. In terms of annual output, the motor-car industry in the period covered has shown a sharp decline every third year since 1918. Its recovery in the current depression has been delayed for the first time and for reasons which will be mentioned later.

It should be apparent from this historical picture that both capital and labor engaged in these four great industries are subject to widely differing hazards of unemployment. This is of vital human importance. The great differences shown and the serious shocks resulting from these repeated surges from plenty to famine and back again warrant the most serious attention to the movements of these important industries. As a matter of fact, all depressions are preceded by periods of abnormal prosperity. These abnormal peaks in business activity demand logical explanation just as much as do the valleys of depression. Any valid explanation will of necessity be substantiated by the facts of business.

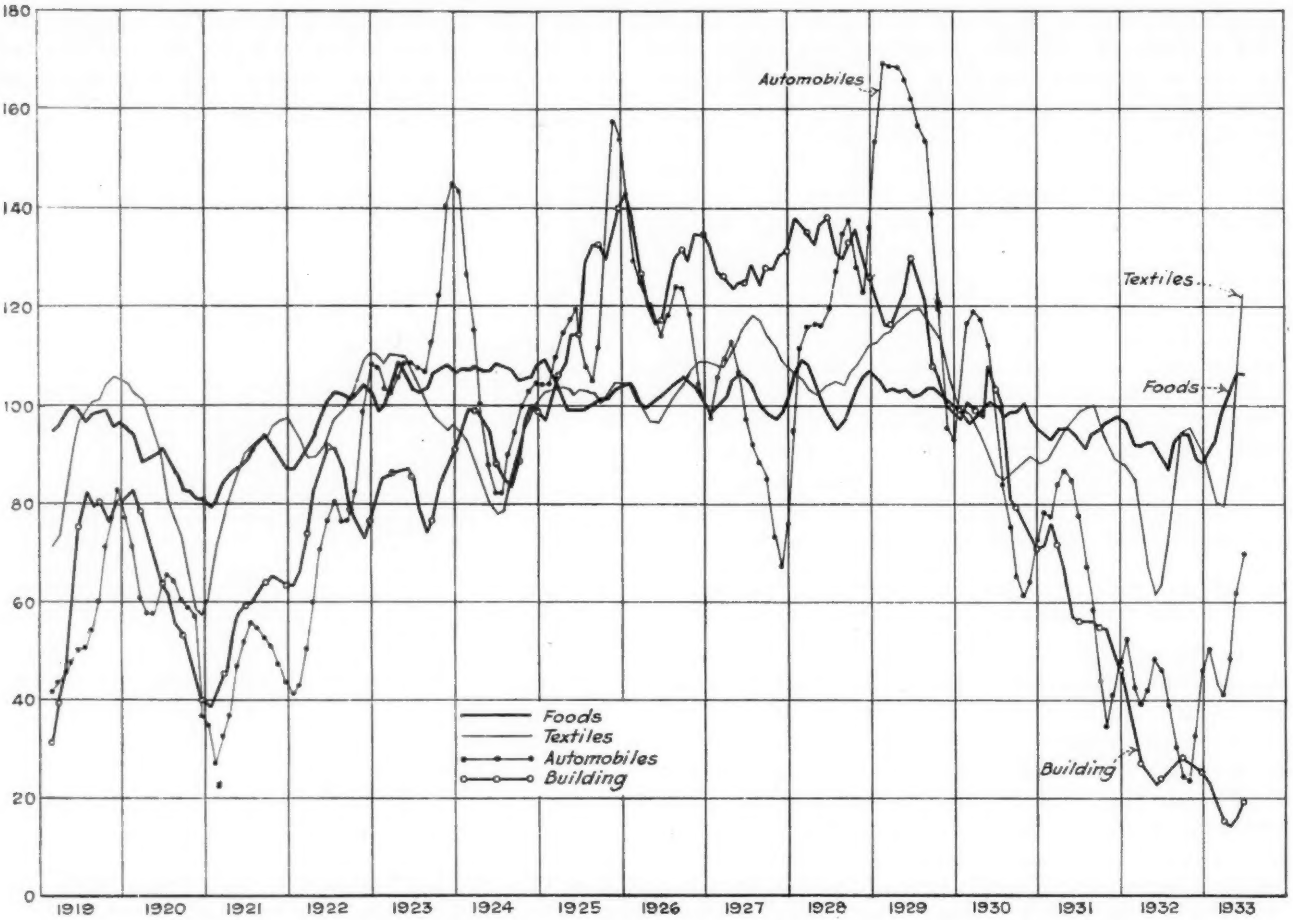


FIG. 3 COMPARATIVE TRENDS OF FOODS, TEXTILES, BUILDING CONSTRUCTION, AND AUTOMOBILES

In order that the simultaneous but differing movements of these industries may be better visualized, they are slightly smoothed by three-month running averages and shown in Fig. 3. Here it may be seen that each industry moving on its own characteristic schedule occasionally comes into agreement in trend with one or more of the others. The four predominant businesses came into agreement downward in 1920 and after this were not again in major agreement downward until 1929. These years marked the beginnings of the last two major depressions. The minor depression of 1924 is marked by relatively serious declines in automobiles and textiles and a slight drop in building construction. The very short depression of 1927 shows a drop in motor-car activity only.

COMPARATIVE TRENDS OF FOODS, TEXTILES, BUILDING CONSTRUCTION, AND AUTOMOBILES

To one familiar with the principles involved in the combination of harmonic and inharmonic wave forms, this varying relationship among the basic industries will assume definite significance. The question will then arise as to what the resultant or composite form will be if these four are combined. When these four indexes are weighted in the approximate proportions in which they exist in the typical family budget and merged in one index, the result is a virtual duplication of the course of all business. This is shown in Fig. 4.

Comparison of Figs. 3 and 4 will show that not only do the depression periods coincide with the complete or partial agreement in downward movements but that the periods of abnormal business activity occur when most or all of these industries are above normal. So-called normal periods occur when the industries are in some degree of opposition.

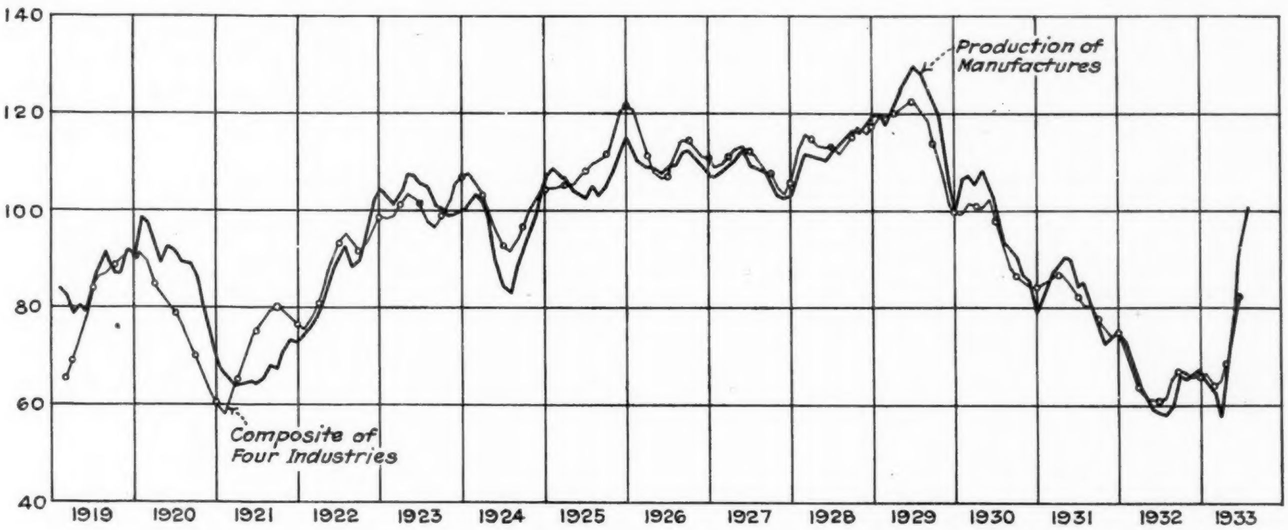


FIG. 4 COMPARISON OF COMPOSITE TRENDS OF FOUR PRIOR INDUSTRIES AND PRODUCTION OF MANUFACTURES

The index of production of manufactures with which the composite index of the four industries is compared is prepared by the Federal Reserve Board, but is converted to the ten-year base. It includes three of the four industries studied in this analysis and all of the others included in the Census of Manufactures. All told, some 16 groups of industries with many components are included in this index. Among them are iron and steel, non-ferrous metals, lumber, machinery, paper, leather, chemicals and oils, rubber, ceramic products, transportation equipment, and others. The close agreement throughout the years, even in the small monthly changes, is not due to a preponderant weight assigned to these four industries in the index of manufactures. Building construction does not directly enter the index of manufactures. The three remaining industries in the four-industry index have a total weight of 75 in 100. In the index of manufactures, these same three industries have a total weight of approximately 31. This is an important point.

The close agreement in the movement of these two indexes throughout the period cannot be due to coincidence or chance. Since it is not due to preponderant weighting in the index of manufactures, the inference may be logically drawn that the four great consumer needs set the pace for all industry. This might be expected on account of the preponderant importance of these industries in human affairs. If the manufactures' index was preponderantly weighted with these four industries, it would be recognition of their vast importance in providing the tempo for all business.

COINCIDENCE OF COMPOSITE AND GENERAL BUSINESS CURVES

We are now brought face to face with the scientific foundation upon which this study rests. The combination of four dissimilar variables, none of which resembles the path of general business but which together comprise a major share of all business, results in a composite trend that duplicates that of general business. It differs from none of the recognized indexes of business in any greater degree than they vary among themselves. The shape of the composite wave is due to the shapes and relative importance of the individual components. An accurate and scientific parallel to this reasoning is involved in the composition of electric and sound waves. Since the shape of the composite wave is due to the individual characteristics of its components, it follows directly that the reasons for the individual variations are the causes of the variations in the composite or average wave which in this case is that of general business.

If these four industries each showed a course like that of general business, this conclusion would not be warranted. The very dissimilarity as to timing of peaks and valleys is a scientific indication that the movements are not primarily due to some common external influence such as credit or weather conditions, sun spots, or other natural phenomena. If the motivating cause of business fluctuations existed in some such external condition,

the effects on the various industries would be both consistent and essentially simultaneous. The peculiar individuality of these industries with respect to both the degree and the timing of the fluctuations should suggest that there may be something inherent in the industries or their products to produce these effects. It is the explanation of these individual movements which we are seeking. It should be apparent that if the reasons can be found, the explanation will be provided for the normal, the high, and the low levels of business. The facts presented showing the behavior of these industries are beyond logical dispute. They are written into the very history of trade.

THE EFFECT OF REPLACEMENT ON DEMAND

Why should some industries vary so little while others fluctuate so greatly, why should the frequency vary, and why should some display a rhythmic or periodic tendency while others show none? Commodities as a whole may be divided into two classes—producers' and consumers'. Each of these in turn may be either short-lived or durable. Consumer goods in particular may also be considered as necessities and luxuries, with no sharp line of division between them. This classification of goods and therefore of industries is basic. It will permit a clearer understanding of the problems involved than the one so commonly used which merely refers to consumption and durable or capital goods.

It is obvious that the purchase and use of luxuries may be more easily deferred or eliminated than those of necessities. Therefore, if an economic crisis occurs, deeper declines in the industries making luxury goods should be expected. This does not explain the deep declines in necessities, such as textiles and residential building, nor in automobiles—a luxury for some but a real necessity for many, based on established location of residence and mode of living. The answer to this involves an economic principle that is not commonly considered. Briefly it is this: The longer the life of a commodity before replacement usually occurs, the longer can be deferment of replacement when a crisis happens.

Food is consumed quickly and as quickly replaced. Biological requirements prevent any great expansion or contraction in its use. Demand and manufacturing production are therefore quite constant as illustrated in Fig. 1. A suit of clothes or a dress will be replaced only at certain intervals. An automobile lasts still longer, and a residence for a much greater period. Replacement of all of these commodities by new ones nearly always occurs before the commodity is worn out. For example, the typical new-car buyer normally replaces his car about every three years, although the normal useful life of the car is predominantly about seven years. Thus, the three-year replacement sets the normal pattern for new-car buying, but there is an additional four years during which postponement of replacement can occur. Shoes, suits, dresses, rugs, and residences are all replaced according to this principle. As the length of life of the commodity increases, the interval between the usual replacement period and the ultimate life increases. Therefore, the opportunity for deferment increases even in necessities. This is a characteristic that applies to the demand for and use of durable goods as distinguished from short-lived goods. Thus, there is no appreciable deferment in demand for staple foods and cigarettes. Demand may be postponed for a short time for replacement of shoes, for a longer time for suits and dresses, and for still longer periods for automobiles and residences in the order named. There are other factors influencing some of these commodities, but the principle outlined is inherent in the goods and their use and is always operative.

Producers engaged in the manufacture of equipment for manufacturing these goods will find that their customers do not commonly expand or renew their equipment during a falling market. Thus the pattern described by variations in consumer demand becomes the guide for activity in the manufacture of the related equipment. It should therefore be obvious that we have in these facts a reason for both the varying degree and frequency of fluctuations among industries.

EFFECT OF REPLACEMENT ON BOOMS AND DEPRESSIONS

The rhythmic or periodic tendency is next to be considered. Before doing this, it will be well to describe a common replacement characteristic that applies to all durable goods. For the purpose of this discussion, durable goods may be defined arbitrarily as those normally lasting more than a year. If a thousand people buy new automobiles in any one day, those automobiles will be replaced over an interval of time, but there will be a concentration of replacement around the normal life before replacement. This means that some preponderant part will be replaced around a given time, influenced largely by style, reliability, freedom from repairs, etc. Many replacements will be made before and after this time but in lower concentration. Nearly 84 per cent of new automobiles sold are usually replaced in the second, third, and fourth years after purchase. A second but similar peak will be found in the age of cars consigned to the scrap heap. This is commonly found to center around seven years. Corresponding peaks may be found in the life of all durable goods, from suits to buildings. The annual replacement of a quantity of goods sold in any one period, if charted, will be found to follow the general outline of the normal frequency or probability curve. It is the resultant, in last analysis, of the law of chance. The tendency of an industry to assume periodic or rhythmic oscillations is promoted by this characteristic.

It should be apparent that the quantity of durable goods sold at any one time determines the quantity to be replaced during the subsequent replacement period. It is a fact that an overwhelming percentage of demand in the basic industries is replacement demand as distinguished from first-time demand. Therefore, any serious distortion in replacement demand is bound to have a marked effect on the industry. If any external event causes a serious change in the quantity of goods sold in any one period, a similar change in the goods to

be replaced will follow in the subsequent replacement period. If the replacement is highly concentrated in a relatively few years, as is the case with automobiles, the subsequent distortion in replacement demand will be serious.

This action may be illustrated by the behavior of the automobile industry. Prior to 1918, it had never suffered a decline in annual output. Intervening depressions had caused a retardation of growth, but not an actual decline. In 1918, the World War caused a reduction in output of 800,000 passenger cars, or 45 per cent of that of 1917. This meant that in the normal replacement period for cars sold in 1918, there would be 800,000 fewer cars to be replaced than for those sold in 1917. Even in those years this was an important proportion of total sales. Since 84 per cent of these would normally be replaced in the second, third, and fourth years, it would cause a reduction of 672,000 cars in replacement demand in these three years. This reduction would center itself near the weighted average period for replacement, which is slightly under three years. Thus, following 1918, a secondary decline would be induced in about three years. This decline would precede any change in income levels and would occur merely because the replacement market was smaller.

As previously stated, the automobile industry, since the first decline, externally caused in 1918, has suffered serious reduction in output every third year, that is in 1921, 1924, 1927, and 1930. Initially, the decline due to the replacement cycle may be a relatively small part of the total reduction finally occurring. The initial decline cannot long continue before it starts a train of progressive unemployment, not only in its own industry, but in others that supply it with materials. This, in turn, induces declines in still more industries, and the accumulative swing is under way. The resulting economic conditions cause a change of plans of many people, and a postponement of replacement normally due will occur. When desire overcomes fear and necessity impels replacement, buying will begin. Normal conditions will gradually return.

Replacement not normally due during the disturbed period has been undisturbed and will occur on schedule when normal levels are reached. But to this will be added the deferred buying from the prior period and demand will then surge upward to abnormal heights. It will again decline following the lower replacement demand set by the prior period. Thus an oscillation in demand is set up which tends to reassert itself. This is a *phenomenon of demand* and may be termed the "replacement cycle." In effect it is similar to the hourly peak in daily buying, the daily peak in weekly buying, and the monthly peak in annual buying, the latter of which we know as the seasonal trend. None of these has its origin in income changes, and stability of income will not eliminate them. The surge due to the replacement cycle is similar in every way, but it occurs at longer intervals and lasts for longer periods than seasonal changes.

When the first break in demand is imposed, those who have been forced out of the market are departing from their normal replacement schedule or have been compelled to defer their first purchase as planned. Following this, however, the buying schedule of these individuals tends to be normal. The surge occurs because more people have now been forced into the market at one time than at another. As just previously stated, this is comparable with the seasonal and other changes in buying volume that are not initially dependent on income changes.

If income initially remains stable and buying declines, what becomes of the surplus income? It would be expected to find its way into some form of savings. That this does happen is indicated by increases in savings, so timed as to be consistent with these composite changes in demand. The timing of these increases in savings has been accepted by some as evidence that depressions are caused by the recurring inability of capital to find stable outlet for the production of new plant capacity. The conception outlined in this study holds that the increases in savings are initially though not exclusively due to decline in buying induced by temporary saturation of the replacement market which is many times more important than original or first-time market and capital extensions for new facilities.

Attention has been called to the fact that major depressions occur when the basic industries are in phase downward. Likewise, abnormal prosperity ensues when they are in phase upward, and so-called normal levels exist when there is some degree of opposition in phase. Once more we may refer to a scientific analogy in the domain of electricity and acoustics. When these industries on their separate paths come into phase agreement, a mutual interaction similar to "resonance" or sympathetic vibration occurs. The fluctuation up or down on the part of each industry will then be greater than if it was not in agreement with the others. The algebraic sum of these distortions will then be larger, which is exactly what happens in periods of extreme prosperity and depression.

Under these conditions, the effect may be to force some industries temporarily out of their accustomed periodicity. The extent to which this can be done will depend upon the degree of necessity for the commodity and its normal life. Clothing is both shorter lived and more necessary than automobiles, and textiles have maintained their periodicity throughout the depression. Automobiles on the other hand, with a three-year replacement life and a seven-year ultimate life, have been forced temporarily out of their stride. There is a four-year period subsequent to the normal replacement life when good service can still be secured. Deferment of replacement has extended into this period in this depression. Former buying habits will undoubtedly be resumed and the same periodicity will follow.

EFFECT OF REPLACEMENT POLICIES ON FREQUENCY OF OSCILLATIONS

It will be seen from the foregoing discussion that there are basic reasons for widely differing fluctuations.

among industries. The importance of any industry in promoting prosperity and depression does not depend upon its economic weight alone but also upon its rapidity and degree of fluctuation. This combined influence may in a sense be called "economic momentum."

The frequency of the oscillations set up in an industry following the first break will depend upon the commodity's normal life before replacement. Evidence in the automobile industry is very definite. More information is needed in other industries. Durable clothing predominates in the textile industry. There is some evidence that style and durability both tend to produce an average life of about two years before replacement. There is also evidence that buildings after 20 years of life become quickly obsolete and are replaced by newer structures. The twenty-year replacement life and possible forty-five-year structural life of buildings compare with the three-year and seven-year life, respectively, of automobiles.

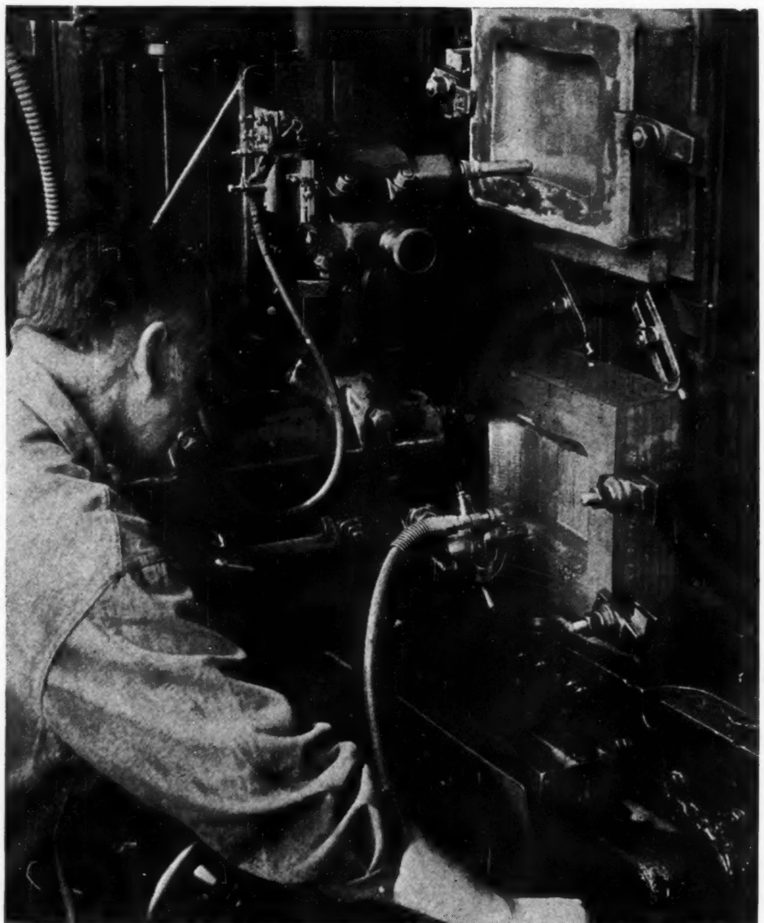
There is some indication that the three-year ripple in the building industry may be caused by the principle of the replacement cycle applied to the ebb and flow of credit in building construction. The large amount of credit impounded at the peak of building activity will not again be released and therefore available for new construction until the expiration of the typical period for which the loans were extended. This seems to center around three years. In this case, the average duration of the loans would correspond to the typical life of the commodity before replacement.

IS REPLACEMENT CYCLE RESPONSIBLE FOR DEPRESSIONS?

Much more work should be done in these important fields. Whether or not the replacement cycle is the cause of the recurring periodicities, the fact remains that the industries do exhibit the peculiarities shown. We are warranted on thoroughly scientific grounds in stating that these individual fluctuations are responsible for the ebb and flow of business. The intervals between fluctuations in those industries exhibiting periodic tendencies are in close accord with such facts as are known regarding the usual life of their commodities before replacement. If the replacement cycle is not responsible for these movements, what is it? The answer to this question is most important. It will be found in a study of the component industries and not of the integrated total.

The conception of fluctuating demand with unchanged income levels has not been considered in advancing the many theories on causes of economic surges. The application of this idea to the problems of the day suggests certain thoughts on sources of recovery and methods of facilitating recovery and stabilization. These provide new starting points for much of this effort. It also helps to clarify many thoughts on the most important elements of credit and price levels. It emphasizes the importance of the ever effective law of supply and demand which can never be repealed by legislative enactment. It bears with particular force upon the problem of wider distribution of income so generally agitated today without reference to the greater economic risks involved therein. It shows the influence of higher standards of living in promoting deeper depressions when they do come. Its thorough interpretation reconciles many divergent theories advanced today. It suggests that war is probably the most potent cause in creating the initial surges of which the recurring depressions are but the continuing echo.

These are all beyond the scope of this discussion, but they may be offered as a challenge for a fresh approach to the problem. If and when it can be demonstrated that these economic catastrophies are not the results of mismanagement by any group of society but are rather the integrated results of the thoroughly natural actions of mankind, a constructive step toward solution will have been taken.



Ewing Galloway, N. Y.

ECONOMIC RECOVERY CANNOT BE COMPLETE UNLESS IT INCLUDES THE INDUSTRIES MAKING CAPITAL GOODS

STEAM *and* POWER SUPPLY

Some General Factors to Be Considered in Planning Steam and Power Projects for Industrial Plants

By VERN E. ALDEN[1]

THE NEED for a new industrial steam or power supply project may develop from:

(1) The construction of a new manufacturing plant.

(2) The expansion or modification of processes in an existing manufacturing plant.

(3) The desire for lower overall costs of steam and power.

(4) The deterioration of existing equipment such as boilers.

(5) The fact that space occupied by existing steam and power producing facilities is needed for expansion of the manufacturing plant.

Plans for such projects assume major importance in some industrial plants, where the total cost of steam and power is in the vicinity of 20 per cent of the overall manufacturing cost and also in large manufacturing plants where the yearly costs of steam and power may be only 2 or 3 per cent of the overall manufacturing cost but still are of such total magnitude as to justify the emphatic question, "Can they be reduced?"

While some of the many interesting technical aspects of planning industrial steam and power supply projects will be referred to, the main purpose of this paper is to discuss some of the broader problems which industrial engineers and executives must face when making decisions involving the investment of considerable amounts of money in steam and power producing facilities.

Many of the most important potential savings relate themselves primarily not to the generation but to the use of steam and power, and before laying down any plan for an industrial steam and power supply project, the required duty must be closely estimated and the following questions should be answered:

(1) Can refinements be made in manufacturing processes which will reduce the consumption of steam or power?

(2) Since the maximum demands for steam and power determine the magnitude of the investments necessary to serve the industrial plant, what can be done to reduce these maximum demands and so improve the yearly load factors at which steam and power are supplied?

(3) Since the investment in alternating-current generators and distribution circuits tends to decrease as the power factor increases, what can be done to improve the power factor coincident with the peak demands for power? By the selection of induction motors which will be loaded to close to their rating and the use of synchronous motors for certain of the large constant-speed drives, it should be possible in most industrial plants to hold the power factor coincident with the peak load up to approximately 90 per cent.

(4) Is the pressure at which steam is to be delivered to the manufacturing plant selected so as to give the best economic result? Too low a pressure may unduly hamper cooking or drying operations, may necessitate the use of too large steam distribution lines, or may require the use of single-effect evaporators for process work, whereas a higher steam pressure would permit the use of three- or four-effect evaporators with an important saving in steam consumption. The lower the pressure, however, at which steam is delivered to process, the greater will be the potential amount of by-product electrical energy which can be generated. This is perhaps most readily visualized by the results of an engineering study which showed that for a fairly large plant with steam produced at 675 lb per sq in. gage, and 800 F, the net by-product generation of electrical energy would be 43, 62, and 74 kwhr per 1000 lb of steam delivered to the manufacturing plant at delivery pressures of 125, 45, and 15 lb per sq in. gage, respectively; and 100 kwhr per 1000 gal of hot water sent out at 180 F. The delivery pressure selected should represent the best compromise between the several conflicting factors. Where uses of process steam are relatively large, it may be advantageous to deliver steam to the manufacturing plant at two or more pressures in order to keep the loss of potential energy generation through throttling of steam down to a minimum. It should be appreciated that stage heating of air or materials in the manufacturing plant will be just as effective in increasing the generation of by-product power as stage heating of feedwater in a condensing steam generating station.

(5) Is provision made for return in uncontaminated form to the boiler plant of the maximum amount of steam condensed in the manufacturing plant? This is important mainly as it relates to improved boiler-plant and turbine-plant operation, but the heat saving is not inconsiderable. The use of forced circulation and the indirect application of heat as recently developed for sulphite-pulp digesters in the paper-making industry is an outstanding example of what can be done to increase the percentage of returns to the boiler plant.

(6) Has adequate consideration been given to the types of drives to be used throughout the manufacturing plant? The substitution of electric drives for inefficient steam drives is, in most cases, constructive. There is, however, a field even in new industrial plants for the use of steam drives in certain special cases.

ESTIMATING LOAD AND LIFE

It is doubtful if any other factor is quite so important in arriving at a sound plan for an industrial steam and power supply project as a reasonably correct estimate of the loads which the power-plant equipment installed will have to carry during its effective life. These loads relate themselves in turn to the probable production of the manufacturing plant and to the uses of steam and power per unit of manufactured product.

If the objection is made that it is exceedingly difficult to forecast the future, the answer may be made that unless the engineers and executives responsible for an industrial enterprise are able with some degree of assurance to forecast the scale of its operations over a period of years, they should not assume

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the business risks incident to an investment in steam and power producing facilities if there is any other reasonable alternative.

For the more stable types of industrial enterprises, such as those producing food products, soaps, and widely distributed commodities for which there is a well-established market, it is not too difficult to make at least short-range forecasts. In planning investments in steam and power producing facilities which will be used only in proportion to the output of the industrial plant, due weight must be placed on each of the factors which may in the future cause a substantial reduction in the steam and electric loads or a complete abandonment of manufacturing operations. The useful life of many industrial power plants has been cut prematurely short by the curtailment or abandonment of related manufacturing operations. The salvage value of an industrial steam and power supply project on the basis of dismantling the plant and selling the equipment will seldom be as high as 15 per cent of the original investment.

Assuming a stable industrial enterprise, it is important to plan the new investment in steam and power producing facilities so that its effective life will be as long as possible. The power plant should not be located so as to interfere with expansion of the manufacturing plant. There should be space provided for a reasonable expansion of the power plant to care for increased loads. In oil refineries, paper mills, packing plants, soap factories, and similar large industrial plants, there is a marked trend toward the use of less steam and more power per unit of factory output. In planning steam and power supply projects for industrial plants of this type, it is wise to design the power plant for a sufficiently high steam pressure so that initially there will be a potential surplus of by-product electrical generation. In such a plant it may be possible to defer the investment in superheaters and high-pressure feedwater heaters until the growth in electric load makes necessary the generation of more by-product electrical energy per thousand pounds of steam delivered to the manufacturing plant.

If there is the prospect of a relatively rapid growth in the steam and power load, the generating units installed initially should be chosen of capacities which will relate more closely to the ultimate than to the initial loads. Any degree of flexibility which can be embodied in an industrial steam and power supply project will tend to lengthen its useful life. This flexibility may consist of: ability to supply to the manufacturing plant steam in varying amounts at several pressures or to take surplus exhaust steam returned to the power plant; the installation of some turbine capacity which can be operated on a condensing cycle; the ability to burn several kinds of fuel; or an interconnection with a utility or another industrial steam and power supply system.

There are many boilers in service at operating pressures of from 100 to 200 lb per sq in. gage, which are from 25 to 35 years old, and a considerable number of turbines and engines still in good operating condition after 20 to 25 years of service. Much of the power-plant equipment being installed today is of a more rugged character than that which was installed 20 years ago. The trend toward the use of higher steam pressures has resulted in thicker walls for pressure parts, has made the equipment safer to operate, and, assuming good operation and maintenance procedure, has increased the life of the power-plant equipment. It may be stated with some degree of assurance that, if properly maintained, the life of much of the industrial power-plant equipment now being installed will be terminated not by its wearing out but by some one of the other factors referred to earlier in the discussion.

REPLACING OLD EQUIPMENT

Fixed charges on the investment constitute so large a part of the overall cost of steam and power that it is seldom possible to justify the installation of new equipment to work on the same cycle and take the place of existing, but somewhat less efficient, equipment. There have been a number of cases, however, in recent years, where it has been possible to install in industrial power plants new equipment to take over the steam and power load, with a resulting reduction in the overall cost of steam and power, including an adequate allowance for fixed charges on the new investment. A typical example would be as follows:

Maximum factory steam load, lb per hr.......	400,000
Yearly steam use in factory, lb...............	2,500,000,000
Maximum factory electric load, kw..........	8,000
Yearly electric use in factory, kwhr..........	50,000,000

Steam is produced from coal costing $4 per ton in two boiler plants, each containing ten boilers of 6000 sq ft area each, generating steam at a pressure of 150 lb per sq in. gage, at which pressure steam is delivered to the manufacturing plant. Approximately half of the process steam is throttled down to a pressure of 20 lb per sq in. gage, before being delivered to process.

The electric power load is generated by means of two 5000-kw condensing turbines taking steam at a pressure of 150 lb per sq in. gage.

A solution which has been adapted to a situation of this sort has been to install one new boiler to produce approximately 500,000 lb of steam per hr at a pressure of approximately 450 lb per sq in. gage. Steam from this boiler is expanded through a new 8000-kw mixed-pressure turbine which delivers a portion of the steam to the manufacturing plant at 150 lb per sq in. gage, and the remainder of the steam is expanded to a pressure of 20 lb per sq in. gage. Steam required for feedwater heating is also expanded through this same turbine.

Sufficient power is generated by the new turbine as a by-product of the process-steam load to supply the entire electric load. This power is generated with an incremental coal consumption of approximately 0.33 lb per kwhr, whereas the coal consumption in connection with the two 5000-kw condensing turbines was approximately 2 lb per kwhr.

Substantial improvements in boiler-plant operating efficiency are made possible by use of the single large boiler, and reductions in the cost of boiler-plant operation and maintenance are effected.

The investment is kept low by the use of the single boiler and turbine.

The two existing boiler plants and the two 5000-kw condensing turbines are held in reserve as stand-by capacity for the new boiler and turbine. It has been demonstrated that with careful operation of such an installation, the steam and electric loads of the manufacturing plant can be carried for at least 90 per cent of the hours in the year on the new and efficient equipment.

ELECTRIC POWER AS A BY-PRODUCT

A power plant generating large amounts of electric power as a by-product of steam delivered to industrial process operates at an efficiency and produces steam and power for overall costs which cannot be approached in even the largest and most efficient condensing steam-generating stations. Table 1 shows for a twelve-month period the actual operating results of a plant which supplies steam and power to an industrial concern and its surplus power to a utility system. All electric power in this

plant is generated as a by-product of the process steam at an overall heat rate of approximately 4250 Btu per kwhr. (This corresponds to 0.31 lb of good coal per kwhr.) For the year 79.6 per cent of all the heat units in the fuel delivered to the power plant was sent out as useful heat either in process steam or electric power. This performance may be contrasted with the best published performance of approximately 28.4 per cent overall efficiency for a 100,000-kw condensing steam generating station operating at 1200 lb per sq in. initial steam pressure.

A station with such a performance approaches the ideal of a primary battery in which the energy of the fuel is transformed directly into electrical energy and useful heat. The overall efficiency of 79.6 per cent for heat conversion leaves but little margin for improvement. A reduction in the pressure at which process steam is sent out, an increase in steam pressure or temperature, or the use of the mercury-vapor cycle would increase the kilowatthours of electrical energy generated per 1000 lb of process steam. As in an oil refinery where the objective is to produce the maximum amount of gasoline per 1000 barrels of crude oil, so in a power plant of the type under consideration it is desirable to transform the highest possible percentage of the total heat in the fuel into the relatively more valuable form of electrical energy, assuming, of course, that there is a use for the power generated.

It is doubtful that five years from now the executives of any stable industry or the utility serving the territory in which that industry is located will view with equanimity the generation of as much as 200,000 lb of steam per hr at low pressure and high load factor, and with a negligible amount or no generation of by-product power.

Important as is the improved fuel economy of such a plant for the combined generation of process steam and by-product power, it must be appreciated that an equally important factor in reducing the unit cost is the thinner spreading of operating labor costs, maintenance costs, and fixed charges over a larger number of units of plant output of steam and power.

CHOICE OF INITIAL STEAM PRESSURE

The choice of initial steam pressure and temperature for an industrial plant hinges mainly on:

(1) The amount of electrical energy which it is desired to generate per 1000 lb of process steam.

(2) The pressures and temperatures at which it is necessary to deliver steam to the manufacturing plant.

(3) The extent to which multi-stage heating of feedwater and air is used so as to increase the amount of recirculated heat, and so increase the generation of by-product electrical energy.

(4) The quality of the water available for make-up to boilers and the percentage of condensed process steam available for return to boilers as distilled water.

It has been demonstrated by three years of operating experience in the plant whose performance, already referred to, has been outlined in Table 1, that satisfactory operation can be had when delivering to the boiler plant as make-up 77 per cent of very badly contaminated river water. The problems of treating this make-up water are difficult but not insurmountable. Very properly there is a hesitancy at present to go to operating pressures appreciably higher than 700 lb per sq in. gage, unless the percentage of make-up water is very low and the quality exceptionally high. It is possible by the use of single-effect evaporators to return all of the condensed steam to the high-pressure boilers and obtain satisfactory operation even though the condensate returns from the manufacturing plant are low. This solution, however, adds appreciably to the investment.

It may be inferred from the earlier discussion that the one thing inherent in the design of an industrial power plant which is most apt to cause it to be ultimately superseded by a new plant is its inability to generate, as a by-product of the process steam load, sufficient power to supply the plant electric load. This constitutes a rather compelling argument for the choice of a steam pressure which, consistent with a moderate investment, will be adequately high.

TABLE 1 OPERATING RESULTS FOR A POWER PLANT FOR BULK SUPPLY OF PROCESS STEAM AND BY-PRODUCT ELECTRIC POWER

(Steam generated at average pressure of 608 lb per sq in. gage, and temperature of 694 F. Process steam sent out at an average pressure of 131.2 lb per sq in. gage, and temperature of 416 F. No condensed steam returned. River water supplied as make-up at average temperature of 71.2 F.)

Month	Total steam generated, lb/10^6	Total steam delivered to process, lb/10^6	Water blown down from boilers, lb/10^6	Electrical energy generated, kwhr/10^6		Kwhr net generation per 1000 lb steam delivered to process	Total fuel to boiler furnaces, Btu/10^9	Fuel to furnaces per 1000 lb steam delivered to process, Btu/10^6	Useful heat absorbed by process steam and in net electric energy generated				Maximum-hours load	
				Gross	Net				Absorbed by process steam, Btu/10^9	Absorbed in net electric generation, Btu/10^9	Total useful heat, Btu/10^9	Total useful heat, expressed as percentage of heat delivered to furnaces, per cent	Process steam, lb per hr	Gross electric generation, kw
1932														
August...	634.4	482.0	64.9	17.59	17.17	35.6	783.8	1.626	567.2	58.6	525.8	79.9	810,000	28,000
September	559.3	424.4	49.3	15.98	15.57	36.7	703.3	1.655	501.1	53.1	554.2	78.9	735,000	28,000
October..	559.8	409.9	50.0	15.14	14.76	36.0	703.7	1.717	483.8	50.4	534.2	76.0	672,000	27,000
November	534.8	397.4	48.1	14.92	14.50	36.5	668.5	1.682	472.9	49.5	522.4	78.1	648,000	25,000
December	537.7	399.7	46.7	15.0	14.6	36.5	670.3	1.678	479.4	48.9	528.3	78.8	690,000	25,000
1933														
January..	539.2	403.9	39.6	15.12	14.71	36.4	669.7	1.658	488.3	50.2	538.5	80.4	667,000	25,000
February.	512.0	389.7	35.5	14.7	14.37	36.9	637.1	1.635	469.0	49.1	518.1	81.4	715,000	26,400
March...	571.4	430.2	41.7	16.4	16.05	37.3	690.5	1.605	514.3	54.8	569.1	82.4	725,000	28,200
April.....	517.0	387.9	40.5	14.71	14.38	37.1	642.2	1.655	461.2	49.1	510.3	79.5	676,000	26,600
May......	513.0	390.3	37.4	14.77	14.43	37.0	642.7	1.647	463.1	49.2	512.3	79.8	663,000	26,800
June......	439.6	332.2	29.4	11.78	11.47	34.5	545.6	1.642	393.2	39.1	432.3	79.2	610,000	24,200
July......	521.3	396.7	47.8	15.23	14.86	37.5	643.3	1.620	468.4	50.7	519.1	80.7	655,000	25,600
Total..	6439.5	4844.3	530.9	181.34	176.87	36.5	8000.7	1.652	5761.9	602.7	6364.6	79.6	......	.....

RELATIVE STEAM AND POWER LOADS

It may be stated with assurance that a constant relationship between the steam load and the power load from month to month and from hour to hour does not exist in any industrial plant. It is usually true, however, that a moderate deficiency of by-product generation for a small percentage of the total time will not result in a serious increase in fuel consumption. The deficiency in by-product generation may be supplied by purchased power, generation of some power on a condensing cycle, or generation of power with steam exhausted to atmosphere. It is interesting to note that with steam produced at 675 lb per sq in. gage, and 800 F, power can be generated with steam exhausted to atmosphere at 15 lb per sq in. gage, with approximately 1.7 lb of good coal burned per kwhr of net generation. In some cases, at least, the best economic solution involves the generation of a limited amount of power with steam exhausted to atmosphere.

SOLUTIONS FOR LARGE AND SMALL PLANTS

In dealing with industrial steam and power supply studies it is difficult to apply the same solution to two different situations, even though they may seem similar in many respects. It is particularly hazardous to generalize from a solution of the steam and power supply problem for a very large industrial plant and attempt to apply the same solution to a much smaller plant. The steam and power needs for two industrial plants of thoroughly stable type are outlined in Table 2.

TABLE 2 STEAM AND POWER REQUIREMENTS FOR TWO INDUSTRIAL PLANTS

	Plant No. 1	Plant No. 2
Maximum factory steam load, lb per hr.	400,000	40,000
Pressure at which steam is supplied to process, lb per sq in. gage............	80	80
Yearly steam use, in factory, lb.........	2,500,000,000	250,000,000
Maximum factory electric load, kw.....	8,000	800
Yearly electric use in factory, kwhr.....	50,000,000	5,000,000
Cost of coal containing 13,700 Btu per lb, dollars per net ton..................	4	4

It is almost certain that the best economic solution of the steam and power supply problem for plant No. 1 would call for the generation of the entire electric load as a by-product of the process-steam load and that the overall unit costs of steam and power would be satisfactorily low.

A new plant built to carry the loads of this larger industrial plant would, perhaps, if built today, contain three boilers, each capable of producing 260,000 lb per hr of steam at 450 lb per sq in. gage, and three 4000-kw back-pressure turbines expanding steam from 450 lb per sq in. gage, to 80 lb per sq in. gage. It is probable that the boilers would be fired with coal in pulverized form, and that forced-draft fans would deliver air to the burners and induced-draft fans pull the flue gas through the boiler. It is probable that a heat-liberating rate of 30,000 Btu per cu ft per hr would be maintained in the furnace, that the rate at which steam would be absorbed by the boiler surfaces would average 17,000 Btu per sq ft per hr, and that the water-storage capacity of the boiler drum would be sufficient for only two minutes of operation in the event that the feed pumps stopped. Economizers or air heaters, or perhaps both, water-cooled furnace walls, provision for removal of pulverized-coal ash as liquid slag, and combustion control would help to complete the outline of this rather complicated but very efficient plant which is largely the result of developments in the large utility boiler plants. Such a design would constitute a good economic solution for industrial plant No. 1.

It would be entirely possible to design and build for industrial plant No. 2 a power plant which, except for the fact that the boilers and turbines would be of one-tenth the capacity, would, in all other respects, be very similar to the larger plant. The operating problems would be substantially the same in the smaller plant as in the larger, and for satisfactory results the same high-grade well-trained personnel would be required. The fuel costs per unit of steam and power sent out might not exceed the unit fuel costs of the larger plant by more than 5 per cent. The unit costs for operating labor and superintendence might be increased by 700 per cent, and the fixed charges on the investment prorated to each unit of steam and power sent out might be increased by as much as 100 per cent. These large increases in the unit costs for operating labor and superintendence and for prorated fixed charges make this a border-line case for which the burden of proof is to show why a low-pressure boiler plant supplemented by purchased power should not be used. The prorated fixed charges and operating labor costs in the very small plants constitute such a heavy burden that even though the fuel cost is low the total overall cost of by-product power may exceed the cost of purchased power. It is particularly important in such a border-line case to consider the probable trend of costs of purchased power and of generated power in the years immediately ahead.

The best economic solution of the problem of steam supply for the smaller industrial plant would call for a much simpler design of boiler plant. The features of such a plant might be relatively simple stokers with a fuel-burning rate not exceeding 35 lb per hr per sq ft of projected grate area; refractory-wall furnaces with a very limited amount of water-cooled surface along the fire line; boilers in which the average rate of heat absorption is of the order of 6500 Btu per hr per sq ft of surface, and the probable elimination of air heaters, economizers, and induced-draft fans. Moderate fuel-burning rates and rates of heat absorption appreciably simplify the operating problems and permit a somewhat less highly trained personnel. The savings in fixed charges, costs of operating labor, and costs of executive attention given to power-plant operating problems will more than offset the increase in fuel costs incident to the use of the simpler and somewhat less efficient boiler plant. Not the least important advantage of the boiler plant of simpler design is that it calls for a lower consumption of auxiliary power.

If conditions are not favorable for the purchase of power, it is entirely feasible to design the simpler boiler plant referred to in the preceding paragraph for a pressure of 450 lb per sq in. gage, and install back-pressure turbines for the generation of the electric load. The problems introduced by the use of the higher steam pressure are mainly design problems, and if the design is executed with proper care the operating problems for a boiler plant operating at 450 lb per sq in. gage, need be only slightly more difficult than those for a plant operating at 150 lb gage. Assuming that proper care has been used in the design, the 450-lb plant would be equally as safe to operate as the 150-lb plant.

RESERVE CAPACITY

There is a trend in industrial power plants to use fewer and larger boilers and turbines. This trend emphasizes the importance of reserve capacity. Unquestionably progress has been made in improving the reliability of power-plant equipment, but we have not reached the end point of perfection. Complete inspection and overhaul of turbine-generators is necessary at least every two years if trouble is to be avoided. A reasonably conservative estimate of outage time for boilers and turbines is as follows:

	Inspections and overhaul	Unforeseen trouble	Total outage
Turbine-generators, hr per year...	550	150	700
Boilers, hr per year............	800	100	900

This estimate assumes painstaking attention to details of the design and careful operating and maintenance practise. The outages given in hours per year are not the maximum to be expected but rather the average for a period of five years. For certain individual cases the scheduled outage time has been reduced considerably below the figures given by careful scheduling and the use of considerable overtime.

For a case such as the one referred to earlier in the paper where sufficient reliable though inefficient reserve capacity is available to carry the whole industrial-plant load, it is a reasonable procedure to install only just enough new and efficient equipment to carry the plant load, and to plan definitely for the use of the older equipment when the new equipment is not available for service. It has been considered good practise in at least four cases to embody the new and efficient capacity in one boiler and one turbine.

A somewhat different problem arises with relation to reserve capacity for an entirely new industrial plant. Two questions must be answered:

(1) Is reserve capacity needed? If the overall costs of steam and power are, perhaps, only 4 per cent of the total manufacturing cost and the cost of labor is a high percentage of this cost, if storage of finished goods is difficult and loss of production, even temporarily, means potential loss of business, then without question reserve capacity is necessary. If, on the other hand, all of these conditions are reversed, the answer is not so clear. It is conceivable that responsible engineers and executives after having carefully weighed all the chances might, with their eyes wide open, lay down plans for a new paper mill with two 100-ton-per-day paper machines and install in the power plant only two boilers and two 5000-kw turbines. For a particular set of conditions, this plan, which includes no reserve capacity in the power plant, might work out very satisfactorily. Such a plan places a high premium on good operation and the careful scheduling of all maintenance work.

In general, the utilities have considered that they should sell only fully relayed service to industrial plants. More recently they have been coming to appreciate that some industries cannot afford to pay for this type of service. There is a field for the sale of unrelayed power. It must be emphasized, however, that some industries require very complete protection against either short-time or long-time interruptions to their power supply.

(2) How much reserve capacity is needed and of what should it consist? If reserve capacity is needed, there should be sufficient reserve so that with the largest boiler and the largest turbine out of service the industrial plant loads can be carried. It is not unreasonable under these conditions to plan for careful scheduling of factory operations so as to curtail peak demands for steam and power, nor is it unreasonable to plan for the carrying of loads on the boilers somewhat in excess of their normal continuous rated capacities. The fewer the number of units in the boiler and turbine plants, the greater must be the investment in reserve capacity. This will, in part at least, be offset by the decreased investment in the normal operating capacity.

Consideration should be given to the purchase of stand-by capacity for the power load.

It is interesting to note that with an annual load factor of 60 per cent for the plant load, the average annual use factor for the equipment in a fully relayed power plant cannot exceed 30 per cent for a two-unit plant or 40 per cent for a three unit plant. A five-unit plant would, however, have a possible average annual use factor of 48 per cent. For such a growing plant there would be a determining reason for omitting in connection with the first two boilers all marginal investments for the improvement of operating efficiency and for adding these refinements on the next three boilers installed.

FUEL-BURNING PROBLEMS

The cost of equipment for unloading, storing, and burning coal and the cost of ash-handling equipment constitute a very considerable percentage of the investment in a small industrial boiler plant. Attractive possibilities present themselves in certain cases where these heavy investments may be deferred and fuel oil or natural gas burned during the initial years of operation of a new industrial boiler plant.

In some industrial plants waste fuels are available for the boiler plant. Acid sludges and tars, wood refuse, black liquors from pulp digesters, and oat hulls, each presents its own special problems. The refuse-burning problem should be carefully fitted in as one component of the larger problem of steam and power supply. Unless there are determining reasons for doing otherwise, the heat released from the refuse should be absorbed in high-pressure steam which will have potential possibilities for power generation. If possible, provision should also be made for burning some more normal fuel, such as fuel oil or pulverized coal, under the waste-heat boilers.

No plan for an industrial boiler plant should be laid down without asking the question, "When will we be asked to minimize the discharge of smoke or fly ash from the chimney and how will we accomplish it?" In some cases, at least, the answer to this question will indicate that provision should be made initially so that dust catchers may be installed when there is an urgent need for them.

ONE POWER PLANT TO SERVE SEVERAL INDUSTRIAL PLANTS

Attractive possibilities are presented by a plan which involves the use of a single power plant to supply steam and power to several industrial plants. The obvious advantages of such a plan are that the reserve capacity is pooled, that it permits the use of larger boilers and turbines, that the investment and the resulting fixed charges prorated to each unit of steam and power sent out are less, that the costs of operating labor and superintendence are spread thinner, and that the coal consumption is less because of the higher efficiency of the larger units. Less obvious advantages are the better balance between steam and power loads resulting from the diversity of uses, and the decreased smoke nuisance. It is probable that the most outstanding advantage, however, is that the investment for capacity in such a plant assumes somewhat less the aspect of a frozen asset and somewhat more the character of a negotiable security. There is always the possibility in connection with such a project that the capacity released through a decreased scale of operation in one industrial plant may be absorbed by an increased scale of operations in one of the other plants. Interconnections between industrial plants for the exchange of steam and power and the use of surplus capacity in one industrial boiler plant to supply steam to an adjoining industrial plant are modifications of this plan, all having as their objective the more effective use of the power-plant investment and the operating personnel. The dollar savings resulting from such a plan must, however, be sufficient to compensate for the sacrifice of freedom of individual action.

A plan such as the one outlined in the preceding paragraph can usually be handled best by the electric utility. The utility

can usually contribute assets to such a plan that will make it possible to supply steam and power to the industries for as low a cost as they could generate it in their own smaller plants of modern design and still earn a reasonable profit for itself. The utility's most important asset in entering into a project of this type is the ability to use its system to absorb surplus by-product power and to supply stand-by service. The utility's organization trained in power-plant operating problems and its ability to purchase fuel advantageously and to borrow money at low rates of interest are other assets. The ideal solution is a utility power plant supplying the needs for steam and power in each large industrial district. A limited amount of condensing operation in such a plant adds to its flexibility and tends to insure a long useful life. A plan which has received far too little active study is the supply of process steam to industrial plants from the large utility central stations operating mainly on a condensing cycle. A major consideration in the location of any new utility central station should be to make it possible to serve steam to a group of industrial plants. Such a plan constitutes the most complete conversion of the industrial power-plant investment into a negotiable asset. Pipe lines of one to two miles length are not too difficult economic obstacles to the transmission of large blocks of steam at high load factor. The art of steam metering has been developed so that there need be no hesitancy in using a well-designed and operated steam-flow-meter installation as the basis of cost allocation, even though the yearly costs aggregate several hundred thousand dollars.

In a few cases the utilities have found it advantageous to build a power plant to supply steam and power to a single large industry.

The utilities have not generally appreciated the fact that if they are to participate on an advantageous basis in such industrial steam and power supply projects they must maintain a potential shortage of power generating capacity on their systems.

As in connection with a single industry, so in connection with a group, no large investment should be made in a power plant unless the industries are of a stable type and there is a fair prospect that the steam and power producing facilities provided will be operated at a reasonably high use factor over a long period of years. It must be appreciated, however, that a diversity of operations is introduced into a cooperative enterprise, particularly one which involves supply to several industrial plants producing different commodities, and that this diversity helps to reduce the business risks associated with the project.

DESIRABLE FUNDAMENTALS TO BE EMBODIED IN CONTRACT RELATIONS

Certain desirable fundamentals should be embodied in the contract relations which are set up to cover these cooperative steam and power supply projects.

(1) Provision should be made for the payment of the fixed charges on the investment in such a way that there will be an equitable division of the business risks.

(2) The contract period should be sufficiently long to permit of amortizing the investment, and provision should be made for the extension of the contract and the continued use of the facilities if this appears desirable.

(3) Throughout the contract period there should be an equitable division of the benefits of the cooperative enterprise.

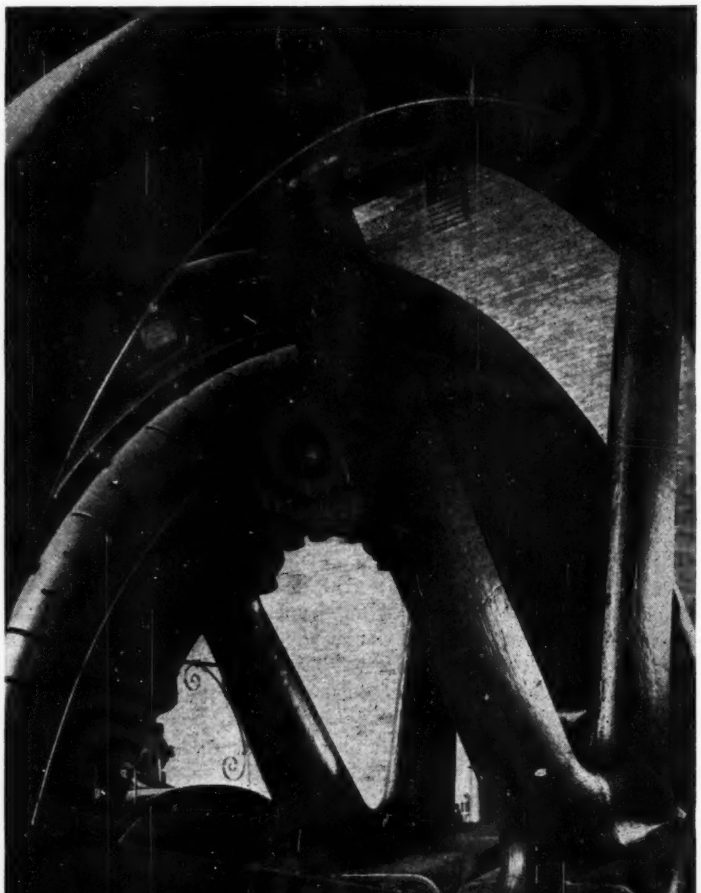
(4) Cost allocations should be made upon the basis of certain agreed-upon principles of equity and not upon fixed unit costs.

(5) There should be a recognition of the fact that future conditions will differ from the present and in any long-term contract there should be provision for review and modification at stated intervals.

EFFECTIVE USE OF EXISTING EQUIPMENT

In the case of many existing industrial power plants, however, it will be found that the need is not for an entirely new plant to supersede existing facilities, but rather for their more effective use and for such modifications as to more nearly adapt these facilities to present-day practise. No plan for the spending of a substantial amount of money in an existing power plant can be considered as sound until it has been determined that the most effective use is being made of the existing investment.

We would not minimize the importance of the most careful and painstaking study of the detail problems of engineering design and operation of each industrial steam and power supply project. Unless, however, constructive, thoroughgoing consideration has been brought to bear on some of the broader problems discussed in this paper, no proper foundation will have been laid for the project.



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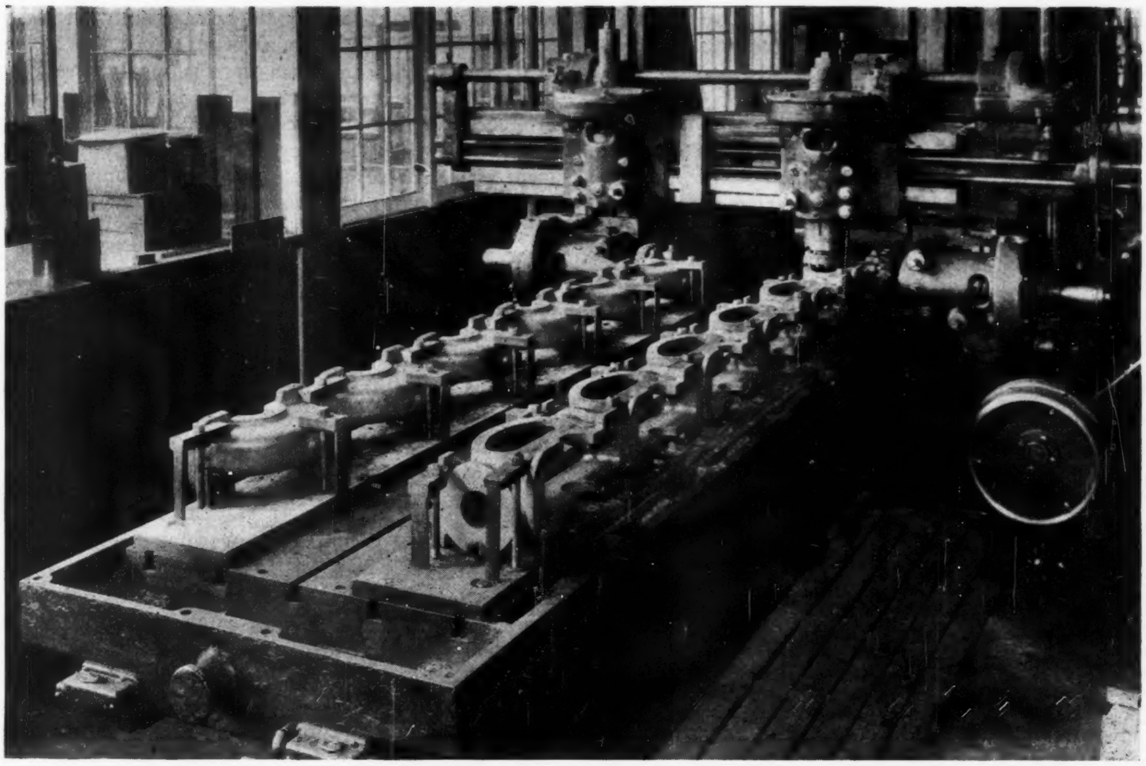

FIG. 1 MULTIPLE FIXTURE FOR MILLING HORIZONTAL JOINT AND EXHAUST FLANGE OF WHEEL CASINGS OF SMALL STEAM TURBINES

PLANING *Versus* MILLING

A Shop Executive Compares Two Methods of Machining

BY A. C. DANEKIND[1]

BECAUSE of the complexity of the economics of planing versus milling in machine-shop practise, it is obvious that whatever conclusions may be arrived at by any individual analysis can hardly be expected to receive the unqualified endorsement of all executives well versed in the subject. This paper is based for the most part on a review of past and present practises of the various manufacturing divisions of the General Electric Company. Several other representative manufacturing concerns have also been consulted in order that a broader and strictly impartial analysis might be presented. The author is particularly appreciative of the whole-hearted cooperation on the part of the other persons consulted.

General Electric records indicate that up to about thirty years ago its typical machine shop listed fully as many planers as milling machines. The very flexibility of a planer made it a particularly valuable asset, for in those days mass production and repetition work as we know them today were unheard-of factors.

About twenty-five years ago, the efficiency of planers was substantially increased by the invention of the reversing-motor drive as a substitute for the conventional cross-belt drive. The great advantage of this drive was that a planer table might be reversed at a much more rapid rate, thus making a complete cycle in much less time. The reversing-motor drive was accepted as a revolutionary advance in the operation of planers, and a majority of the planers in the country, except those of particularly small capacity, were changed over to take advantage of this new method of driving.

Practically all of the several hundred planers in the General Electric shops had been changed over to reversing-motor drive by 1913. In spite of this fact, the records indicate that starting in 1916 one job after another was transferred from a planer to a milling machine, the planers affected, however, being of about six-foot capacity and smaller. This transition, while gradual, was very definite, so that a large percentage of the production jobs done on planers in 1916 are now being done by milling machines. The few planers used today are either particularly large ones doing exceptionally large work, or small machines in toolrooms where they are being operated in preference to

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milling machines because of their flexibility. This transition is not unique with this company, as the records of several other concerns reveal similar facts.

REASONS FOR SUBSTITUTING MILLING MACHINES FOR PLANERS

Probably the chief reason why milling machines have supplanted planers to such a great extent is because the principle involved in milling permitted wide exploitation and development. Modern milling machines are like only in principle those of twenty years ago. Present-day planers, on the other hand, do not differ substantially from those of an earlier date, except for greater rigidity. Milling-machine manufacturers have developed their product to a point where the prospective purchaser has his choice of any one of several types, each of which has features not to be found in any of the others.

Probably one of the chief reasons for the rapid development of the milling machine was the general demand made by automobile manufacturers for more productive machine tools. The rapid growth of that industry during the past twenty years entirely justified elaborate and expensive engineering efforts on the part of machine-tool manufacturers, and particularly those interested in milling machines. Conditions existing in automotive plants necessitated the use of mechanical equipment for making great quantities of interchangeable parts, quite small in size, and with a minimum amount of stock removal. In meeting these conditions, milling-machine manufacturers have accomplished a noteworthy achievement. Other industries have obviously benefited from a development that would hardly have been possible were it not for the incentive offered by automobile plants.

Milling-cutter manufacturers have developed their product also. While it is probably a fact that improvements in cutting tool steels have made it possible to control hardening distortion to a minimum and produce more efficient cutting edges, the devotion of thought to proper designs of cutters for specific requirements has resulted in an important contribution to efficient milling-machine operation. During the past decade, cutter manufacturers have also made an important contribution in the development of inserted-tooth cutters as distinguished from those of the solid type. This has made possible additional economies in milling practise. Cutters are being regularly produced to limits of plus or minus 0.0005 in., and even this working tolerance is reduced as occasion requires.

In summing up the reasons for the substitution of milling machines for planers, the following appear to be outstanding:

(1) The principle involved in planing does not permit wide engineering development or practical exploitation.

(2) The principle involved in milling has offered a particularly wide field for development.

(3) The progress made by milling-cutter manufacturers in the design and construction of their product to suit specific requirements has contributed substantially to the advance which has been made in the art of milling.

(4) Metallurgical advance in the cutting quality of tool steels has had a greater effect on the development of milling cutters than on the development of single-point planer tools.

DECIDING WHICH TO USE

There is no questioning the fact that a planer is still a very important factor in general machine-shop practise under present-day conditions. In certain cases, and assuming that equipment is available, a planer is decidedly the proper machine for the job. Its flexibility is such that shapes of great variety are within its capacity. Tool cost per piece produced for parts machined to shape on a planer is substantially lower than that involved in milling similar parts. In the construction of large turbines, single parts, usually castings of great size and peculiar shape, must be machined, and a careful cost analysis frequently indicates that planing is more economical than milling. Planers are a vital factor in the economical production of certain parts required in this line of work.

It is obvious that wherever both planing and milling equipment are available, an accurate analysis must be made of all influencing factors involved in each individual job before it can definitely be asserted that one might be used to advantage rather than the other. A general procedure for job analysis to determine as accurately as possible the relative advantages of the two types of machines is outlined in the following paragraphs.

In attempting to determine the economics of planing as compared to milling, proper consideration must be given three important conditions as follows:

(1) Nature of work
(2) Machine operation and maintenance
(3) Tool and fixture costs and maintenance.

NATURE OF WORK

Large pieces and parts with particularly long finished surfaces are usually produced in small quantities, a single piece sometimes constituting an entire manufacturing order. Planing can usually be proved to be more economical under such conditions because of the large investment necessary for the milling machine and the milling-cutter equipment. The flexibility of a planer is such that parts having a great variety of sizes and shapes are within its capacity, and for that reason it is relatively more efficient than a milling machine.

Small pieces, regardless of quantity, can usually be milled more economically. The amount of stock to be removed in machining to finish dimensions is usually small. Investment in milling-machine equipment would normally be less and offer the possibility of a faster rate of metal removal. Only in a jobbing shop or in a toolroom doing a miscellaneous line of work can it be proved that a planer is more economical to operate in machining small parts.

Moderate-size pieces present a more difficult problem than do large or small pieces. Further analyzing must be done before the true economics of the subject can be determined. The following additional conditions must be given consideration:

Shape of parts and area of surface to be machined
Number of parts to be produced
Amount of stock to be removed
Nature and characteristics of material
Surface finish required.

Shapes of parts well adapted to planing are those with flat surfaces where the cutting tool might be engaged in the work at least 75 per cent of the cutting stroke. Castings are frequently designed with surfaces and hollow center sections, so that only the outer portion of the surface is to be machined. Usually under such conditions it can be proved that milling is more economical because only a relatively low percentage of the total cutting stroke of a planer would be used. Fig. 1, showing a set-up for machining certain cast-iron turbine parts, more clearly illustrates this point. Incidentally, the fact might be mentioned that up to within a year or so ago this particular part was planed, but by transferring the job to a milling machine the pieces are now being machined for approximately 40 per cent of the former cost.

Complicated surfaces with keys, rabbets, angular pads, etc. can usually be more economically planed than milled. This is particularly true of parts machined in small quantities. Thin light sections can also be planed to good advantage, especially

where the pressure exerted by a milling cutter might spring or distort the piece. Milling is usually more economical on flat surfaces, particularly those located at intervals, such as bosses, pads, etc. Also, it is frequently possible to justify a form cutter or profiling installation in spite of relatively low quantity wherever unusual shapes of sections are to be machined.

The number of parts to be produced determines to a great extent the method of machining. Assuming that both planing and milling equipment are available for a given job, and that the particular piece is of such nature that it might be readily machined by either method, the number of parts involved is usually the determining factor. No general rule can be applied covering this point. A careful analysis of each individual job is necessary before the fact can be definitely established that one machining method is more economical than the other. Only by a careful cost analysis can it be determined whether a milling machine, with a lower direct-labor cost but with a higher attendant tool cost per piece produced, or a planer where the reverse is true, is the more economical machine to use.

The amount of stock to be removed is not usually a factor on pieces of small or moderate size. Designers in laying out parts aim at an absolute minimum of stock removal by the machine shop and a minimum of difficulty which might develop in producing such parts in a foundry or forge shop. While it might be argued that the removal of only a small amount of stock favors milling as the more efficient method of machining, the point is hardly one of particular importance. It is difficult to visualize a condition where milling might be proved more economical solely on the basis that the part in question has but a small amount of stock to be removed. On the other hand, wherever a condition does exist requiring the removal of a substantial amount of stock, it is probably a fact that planing is relatively more efficient than milling. The effect of the amount of stock to be removed on the economics of milling versus planing small or moderate-size pieces might easily be emphasized far beyond its importance as a truly influencing factor.

The nature and characteristics of the material being machined are important factors. Frequently these two points may determine the most advantageous method of machining. Materials might be classified into three groups in accordance with their general physical characteristics. The first group includes non-metallic materials such as bakelite, hard rubber, fiber, molded compounds, carbon products, etc. Milling has a definite advantage over planing in this non-metallic group of low-tensile-strength materials, for the most part non-ferrous metals such as copper, aluminum, brass, bronze, bearing metals, etc. Cast iron might also be placed in this group because of its comparatively low tensile strength and its lack of extreme density. All metals included in this group with the exception of cast iron can unquestionably be machined to size more economically by milling than by planing. Cast iron, of course, lends itself equally well to either method of machining. The third group includes the high-tensile-strength metals such as ordinary steel castings or forgings, or those of nickel steel, chrome nickel, chrome vanadium, manganese, non-magnetic, and stainless steels. Materials in this group are obviously more difficult to machine regardless of the method employed, because of their greater density and higher tensile strength. It is doubtless a fact that metals in this group can be planed or milled equally well. Milling-cutter cost per piece produced, however, might be expected to be substantially higher than that for producing a similar part of cast iron, because of the less favorable degree of machinability of the material.

Castings containing hard spots, blow holes, or sand inclusions usually have a more destructive effect on a single-point planer tool than on a milling cutter. Each tooth of a cutter acts as an individual cutting tool. A few teeth of a milling cutter may become badly affected, but usually a sufficient number of unaffected teeth remain to permit the completing of a job. A single-point tool, on the other hand, is rendered completely useless for further work until it is replaced or reground.

Surface finish of a high quality is a factor frequently mentioned as being more readily obtainable by planing than by milling. The experience of the General Electric Company does not bear this out entirely. In the practise of this company it is felt that an efficient milling-machine and milling-cutter set-up will produce a sufficiently high quality of surface finish to be acceptable from an engineering standpoint for all but a few special cases. Isolated cases do exist, however, where a planed surface is definitely recognized for its superiority over a milled surface. An illustration is in steam-turbine construction where steel castings have steam-joint surfaces.

It has been an accepted fact for years that planing is the most practical means of accurately machining guide ways in machine-tool construction. This method is practised almost universally by builders of machine-tool equipment in the belief that more accurate results can be thus obtained than would be possible through milling. It is significant, however, that one of the manufacturers of milling machines completely finishes the surfaces of guide ways of a planer-type milling machine by means of milling. The fact that the product of this concern is well and favorably known for its satisfactory performance, would seem to indicate that milling offers certain attractions for such work wherever the number of parts is sufficient to justify the necessary investment for proper milling equipment.

MACHINE OPERATION AND MAINTENANCE

In the operation of one or more single-point tools in a planer, more attention is usually required to tools and tool setting than is the case with the milling machine, because a single-point tool will not maintain its dimensions as long as a multi-point tool. This is true in shaft turning and other similar jobs which are done on machines of a type quite different in principle from either the planer or the milling machine, but which employ single-point tools. A certain amount of clearance or rake must be provided in the cutting tool, and because of this fact an increasing amount of the cutting edge is gradually worn away by the pressure exerted in making a cut and the constant abrasion to which the tool is subjected. A multi-point tool, such as a milling cutter, is better able to resist such destructive effects, because every tooth or cutting edge is in reality an individual cutting tool. This objection is valid only in connection with the machining of flat surfaces, for where special shapes are being produced to close limits on a milling machine, even a slight amount of wear on a cutter will be objectionable. This factor is of real importance in determining the economics of planing and milling, however, and particularly in the machining of small parts. In operating either type of machine, loading and cutting can frequently be accomplished simultaneously through the use of a multiple platen arrangement.

A set-up for milling a small quantity of work where special clamping fixtures are not justified and for work of irregular shape or light section would be substantially more elaborate than for planing. Experience in such cases indicates that provision must be made for holding work against greater strains in milling operations. This condition does not apply to quite the same extent where pieces are symmetrical in shape and thus permit ready clamping. In planer operation, however, an increase in weight of pieces to be machined necessitates

greater security in clamping in order that the work may be rigidly held against the inertia forces. This is particularly true where a heavy cut is taken at high speed .

Little can be said relative to planer maintenance except that it is obviously essential to provide proper and adequate lubrication. A planer, with its comparatively few movable parts, is a particularly long-lived machine. The maintenance of a milling machine, on the other hand, is much more complex. A spindle can only serve efficiently when it runs true. Spindle bearings must be maintained in proper adjustment at all times. The quill and head must be securely clamped during a cutting operation. Great care must be given to the proper rate of metal removal, which involves the surface speed, depth of cut, and feed per tooth of the milling cutter. Proper precaution must be taken in handling a milling cutter to provide against accidental damage to the cutting edges or, in the case of a face mill, the back face of the cutter. Particular care must be applied in mounting a face mill. It must be properly and adequately secured to the spindle nose, the bearing face of which must be square with the spindle axis. The run-out of a milling-machine arbor must be held to a minimum, and an arbor should only be operated under load when properly supported on the outboard end.

TOOL AND FIXTURE COSTS—CONCLUSION

The costs of fixtures for pieces that are adapted to either planing or milling should be essentially the same. Experience indicates, however, that a milling fixture should be somewhat stronger and more rigidly constructed. In machining small parts, the best planer efficiency can usually be obtained with a fixture which permits the planing of several pieces at one setting. Furthermore, it is frequently an advantage to operate two planers simultaneously. Such an arrangement necessitates a duplication of holding fixtures, however, whereas a single fixture for milling would be sufficient in most cases.

The cost of cutting tools for a planer is insignificant compared to the cost of tools for a milling machine. Comparatively few single-point planer tools need be provided for a great variety of services. On the other hand, a considerable quantity of milling cutters is required in order that a proper size and design of cutter may be available for each individual job, as the performance efficiency of a milling machine is influenced to a considerable extent by the capability of a milling cutter.

The reconditioning of a planer tool is a comparatively simple matter and is usually done by the operator. Milling cutters, on the other hand, must be reground by skilled mechanics, usually employed solely for that purpose. This involves the provision of efficient and properly adapted grinding equipment, for in re-sharpening cutters, correct clearance and extreme accuracy are essential. It is definitely indicated, therefore, that overall milling-cutter costs are substantially higher than those of planer tools.

A general discussion of the economics of planing as compared to milling has been presented for appraisal. No hard and fast rule can be offered. All influencing factors governing each individual job must be considered before an accurate analysis can be made. It should be noted also that this paper has been based chiefly on the conditions involved in machining moderate or "in-between" sizes of pieces, for therein lies a field for both planers and milling machines. In spite of the fact that many pieces are now being milled which were at some time or other planed, there can be no question relative to the value and usefulness of the planer. In certain cases the facilities offered by a planer are such that a particular condition can be met by no other machine tool; for example, some semi-concealed surfaces can only be machined with an off-set single-point tool.

A careful survey of conditions in one large plant reveals the fact that many jobs have been transferred from a planer to a milling machine, but in no instance do the records of this plant indicate the changing of a job from a milling machine to a planer for economic reasons. Milling machines are by far the more popular type of equipment in these days of never-ending effort for lower manufacturing costs. This fact is at least partially recognized by one manufacturer of planers in the announcement of a new machine incorporating all the features of an up-to-date planer with the addition of two motorized milling heads mounted on the rails.

The greatest single recommendation for the operation of a planer today is its broad flexibility, and for that reason, if for no other, it will always be a real factor in general machine-shop practise.

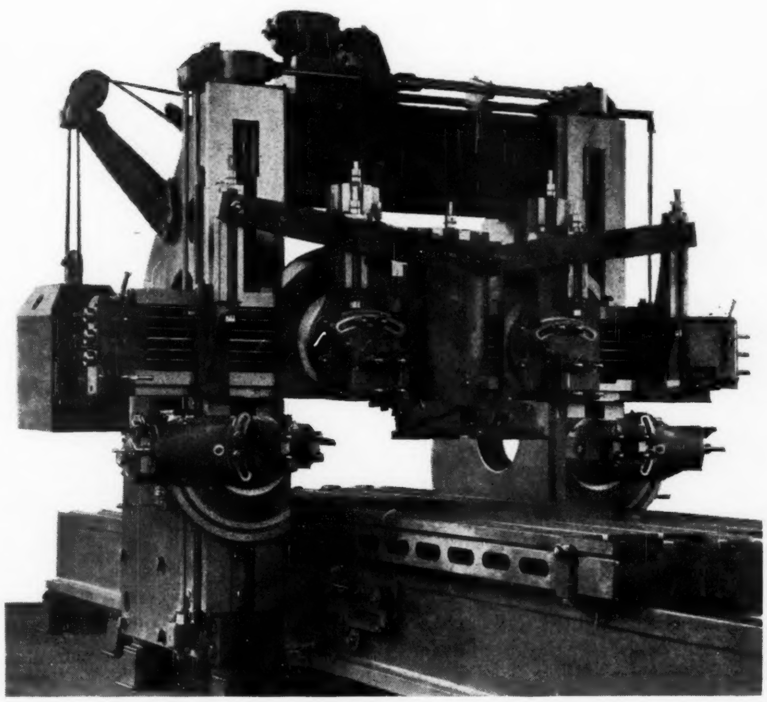
FIG. 2 MILLING MACHINE ARRANGED FOR MILLING A NUMBER OF SMALL CASTINGS

The CASE *for* PLANING:

The Designer of Planers Compares the Advantages of Planing and Milling

By FORREST E. CARDULLO[1]

THE PLANER and the milling machine may be compared from a number of standpoints, such as rate of removing metal; cubic inches of metal removed per minute per horsepower; production measured in pieces produced per day; first cost of a machine of a given capacity, either in size of work handled or in pieces produced per day; cost of maintenance, including tooling and fixture costs; versatility; ease of set-up of work and of tools; accuracy of work produced; quality of finish produced; and kind of work for which each machine is adapted.



PLANER FOR SIMULTANEOUSLY PLANING THREE SIDES OF EACH OF TWO ROWS OF STEEL CASTINGS. THE SIDES OF THE CASTINGS ARE VERTICAL, AND THE TOPS ARE PLANED AT A SMALL ANGLE TO THE HORIZONTAL. SIX TOOLS ARE AT WORK SIMULTANEOUSLY

In this discussion, I shall assume that the latest types of planers and milling machines are to be compared. It is useless, for purposes of comparison, to consider three-fourths of the planers and more than half of the milling machines now in use. There are in the United States about 19,000 planers, and of these about 14,000 should be thrown into the cupola. It is probable that obsolete milling machines can be found in nearly the same relative proportion. Also, I shall not consider work too small to be done economically on a planer.

RATE OF REMOVING METAL

Consider first the rate of removing metal. There are three tools which are preeminent in this field: the planer; the so-called rotary planer, which is in reality a highly specialized form of miller; and the boring mill. While milling machines can be designed which will remove metal at a faster rate than four-head heavy-duty planers, such machines have little commercial application, and are therefore seldom built. The rate at which metal can be removed on a medium-size planer is limited only by the power of the motor and the ability of the work to withstand the tool pressure. When large rectangular surfaces are being machined, the planer can remove metal faster than any other type of tool, because of the fact that it is practical to take deep cuts and coarse feeds, and to use a number of tools at the same time.

This does not mean that the planer can, in the usual run of medium-size work, remove metal faster than the milling machine. The planer works to better advantage in the removal of metal when it takes a fairly deep cut. If the amount of finish is small, the milling machine can remove metal more rapidly than the planer, especially if the planer is "cutting air," as the saying goes, a large portion of the time. Take, for instance, the two flat surfaces which form the top and bottom of the cylinder block of an automobile. These surfaces may be planed, but the castings come accurately to form, the amount of finish to be removed is small, the surface to be machined is only a fraction, and sometimes a rather small fraction at that, of the total area over which the tool must pass, and the conditions are altogether favorable to the milling machine. Wherever thin edges, strips, pads, bosses, and surfaces of irregular outline are encountered, the milling machine becomes a competitor of the planer in the rate of metal removal, and under many conditions may prove greatly superior.

So far, I have been considering only the stronger materials, such as cast iron and steel. When we come to weak materials which can be machined at high speed, such as leaded brass and aluminum, the planer usually cannot work to the same advantage as the milling machine. There are, however, a few cases where, even under such conditions, the planer may have a commercial advantage. Some years ago two planers which operated at a cutting speed of 200 fpm were built for a

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German firm manufacturing knitting machinery for the purpose of planing aluminum guides for some part of its machinery. Just why the firm chose the planer instead of the milling machine for this purpose, I do not know, but it had carefully investigated the matter, and that was its decision.

When hard and tough materials are to be machined, the planer will usually remove metal at a much faster rate than will the milling machine. Switch planers, which work on unannealed steel rails containing 0.90 per cent carbon and 1.10 per cent manganese, illustrate this point. It is not uncommon for a switch planer to take two cuts, each $^1/_8$ in. deep and 3 in. wide, at the rate of 25 fpm in such material. This is at the rate of 225 cu in. of steel a minute, removed by two tools. Allowing for the overrun, reversal, and return stroke, this would be at the rate of more than 125 cu in. of metal a minute, which is no mean accomplishment. While a rotary planer will remove metal at approximately the same rate, the cost of maintaining the cutters in proper condition when working in such materials is prohibitive, because as soon as one blade fails, an extra chip load is thrown on the following blade, which quickly fails, and the machine must be shut down until the cutter has been replaced or resharpened.

METAL REMOVED PER MINUTE PER HORSEPOWER

In the matter of cubic inches of metal removed per minute per horsepower, there will again be found a field in which the planer excels and one in which the milling machine excels. In most cases where the work is of medium or large size, especially in material of high tensile strength with a normal amount of finish, the planer uses less work per cubic inch of metal removed than does the milling machine, in spite of the fact that work is required to reverse the table and to return it to the starting point. This is due to the fact that the milling machine cuts thin chips, and often abrades the work with these chips. The less distorted and broken up the chip, and the larger its cross-section, the less the work required to remove it. The planer tool, when properly ground, removes the chip under the most favorable conditions possible. The milling machine, because the lip and clearance angles of its cutter blades are more unfavorable and because it cuts thin chips and cuts them up into small pieces, requires about twice the horsepower at the tool point as the planer, for a given rate of metal removal, with ordinary cuts, and about 50 per cent more with well-shaped extra-heavy-duty milling cutters. It is only in the case of light work, where friction within the machine absorbs a considerable part of the power supplied, that a modern milling machine equipped with anti-friction bearings will have a lower power consumption than the planer.

PIECES PRODUCED PER DAY

In the matter of pieces produced per day, we must distinguish between four different classes of work.

(1) Work produced in quantity where the planer has an advantage over the milling machine either because the milling machine will not remove metal as rapidly with a reasonable power consumption and general overhead cost as the planer, or because it will not produce a satisfactory finish for the particular purpose, or because it will not produce work of sufficient accuracy for the purpose.

(2) Work produced in quantity where the finish and accuracy produced by the milling machine are satisfactory, and the milling machine can remove metal more rapidly than the planer.

(3) Work produced in small quantity and large variety where the superior versatility of the planer enables the operator to produce a larger output than can be done with the miller.

(4) Work produced in small quantity where standard milling cutters and other equipment may be used to advantage and the work so routed that the set-up time in the milling machine is comparatively small.

In general, when a large production of accurate work is required, or a superior finish is required, the planer can be tooled up and provided with fixtures, gages, and other equipment for doing the work at much less expense than the milling machine, and will usually do the work at less cost per piece. In some cases, it is just as desirable to build special planers for specific purposes as it is to build special milling machines. The finishing of the guide rails for elevators is a case in point. Such planers are usually provided with 48 tools, 40 of which work simultaneously, and with fixtures for quickly aligning the rails and clamping them in place. Such a planer will finish eight rails, each 16 ft long, with an aggregate finished surface of about 43 sq ft, in 22 minutes floor-to-floor time. The smoothness of the cut and the accuracy of the work are superior to what can be produced by a milling machine. The planer is working under favorable conditions, since the surfaces machined are long and narrow, and although the amount of finish removed is small, the great number of tools operating at the same time compensates for this.

In machining large steel forgings and castings having large areas that are relatively long, the planer again works to great advantage, because of the higher rate of removing metal. If a number of short pieces which must be accurately machined, such as slides or guides, can be placed in line with one another, and the entire series planed in one operation, the planer can be made to work under very favorable conditions.

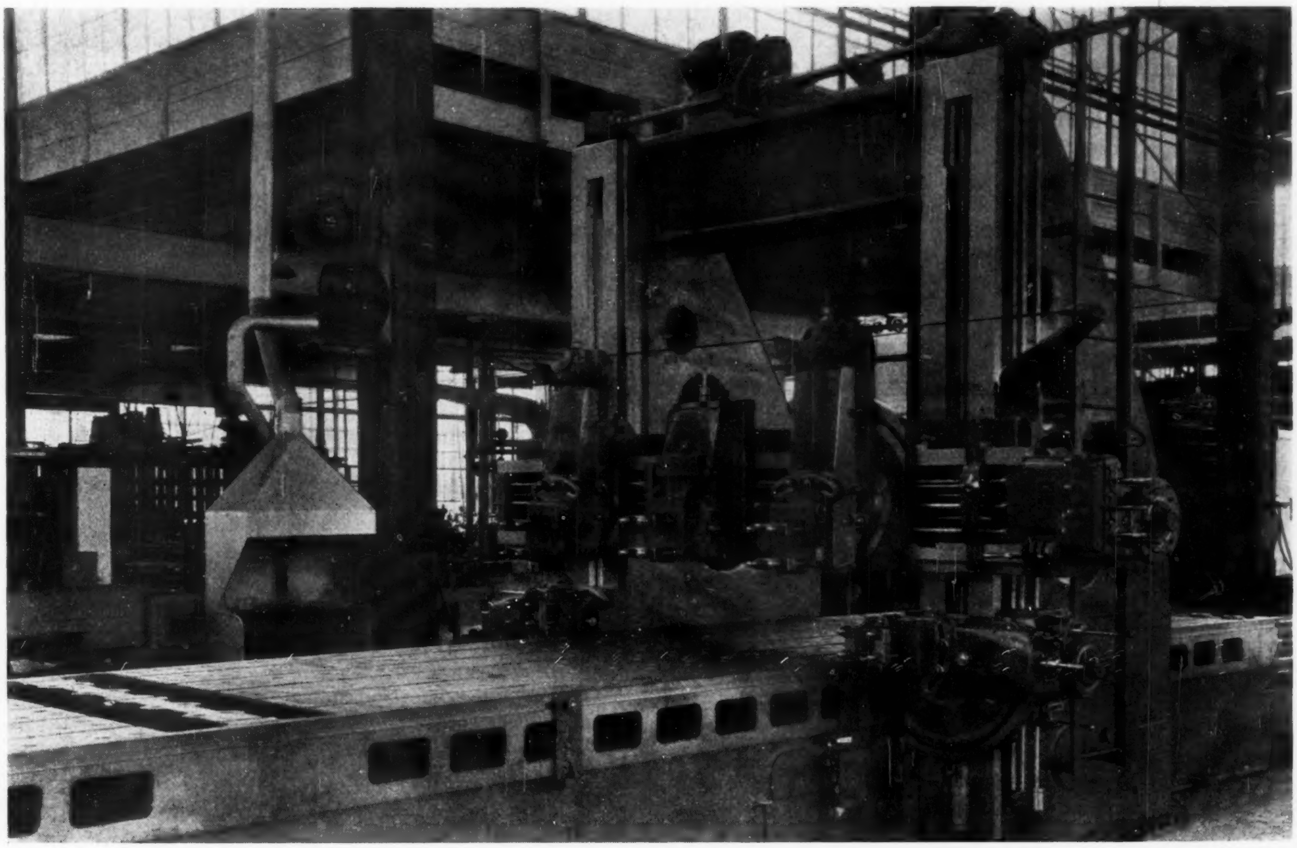
The cylinder block on an automobile has been spoken of as a milling-machine job. Here, both the finish and accuracy of the work produced by the milling machine are perfectly satisfactory, if the machine and cutters be kept in proper condition. In this case, while a planer with special tooling and equipment may produce five or six times the amount of work which the ordinary operator would get with a planer having such tools and equipment as could readily be picked up around the shop, the planer is still not as satisfactory as the milling machine.

FIRST COST

In the matter of first cost of machine to handle work of fairly large size, the planer is cheaper than the milling machine, especially if we include in this cost the necessary cost of tools for the two machines. However, the first cost of a milling machine to produce a given number of pieces per day is usually less than the first cost of the planer equipment necessary to produce the same number of pieces per day. If the milling machine will produce satisfactory work, and there is sufficient production to warrant its purchase, the milling machine then becomes the cheaper tool to buy. If, however, a milling machine is capable of producing a hundred pieces per day, and the requirements are one thousand pieces per year, or if the milling machine will not produce work of sufficient accuracy or quality of finish, it is obvious that in spite of its superior capacity in pieces per day, the milling machine will not be the proper tool to buy.

VERSATILITY

In the matter of versatility, the planer is, of course, very far ahead of the milling machine. Often a planer will do a job with such tools as may be contrived by the foreman and the shop blacksmith before the production-engineering department can design the tools to do the job on the milling machine. The planer is always ready to undertake any kind of job on a



PLANER WITH TWO 20-FT DUPLEX TABLES. SPECIALLY DESIGNED TO PLANE THE SLOTS OF 90-TON TURBINE-GENERATOR ROTORS AT HIGH CUTTING AND RETURN SPEEDS

few hours' notice. The milling machine is never ready to undertake a job on short notice unless the job is simple or the tools for doing it are already on hand. It therefore follows that for jobbing work, for repair work, and especially for emergency repairs, the planer will usually be superior to the milling machine. A planer is readily set to cut work at any angle, and the tools used are almost always easy to make and simple in form. Even on jobbing work which can readily be milled, the planer is often the better tool to use.

Because of its vers. ility and the simplicity and cheapness of the tools and equipment required, the potential field of the planer is very broad, and while the potential field of milling machines in general is equally broad, the potential field of any particular type of milling machine is relatively narrow.

ACCURACY OF WORK PRODUCED

In the matter of accuracy of work produced, it must be remembered that, as commonly used, the planer and milling machine fall, respectively, into the category of generating machines and forming machines, although the milling machine sometimes employs the generating principle, as in milling the races of ball bearings, while the planer is sometimes employed as a forming machine by using a wide forming cutter. In general, generating machines are more accurate than forming machines because of the principle upon which they work. In the case of a generating machine, the accuracy of the work done depends only on the rigidity of the machine and on the fit and accuracy of the various sliding surfaces, and is quite independent of the form of the tool used. Furthermore, the cutting edge of the planer tool, when generating finished surfaces, is usually a straight line. The edge itself is easily generated and readily held in proper relation to the work. In the case of the milling machine, in addition to the errors introduced by the deflection of the machine and inaccuracies in the forms and fits of its sliding surfaces, errors arise in mounting the revolving cutter, there are errors in the original form of the cutter, and errors are introduced by incorrect grinding of the cutter. These errors may or may not be cumulative, depending on the excellence of the equipment employed and the intelligence with which it is used. However, the errors are usually so great as to forbid the use of milled surfaces where great accuracy is required. When a milling machine is used for manufacturing operations, the toolroom procedure and the design of the machine may be such as to minimize these errors, in which case first-class manufacturing milling compares favorably in accuracy with ordinary planed work. In the case of work requiring unusual accuracy, as in machine-tool construction, milling is not satisfactory unless it is supplemented by grinding, and planing is greatly preferred for slides, dovetails, and flat fits. Because of this, work is often rough milled on one machine, left to "season" for a few weeks, and then finish planed on another machine, although such procedure is usually unnecessary and wasteful. In many cases, the work can be rough planed, unclamped, repacked, and finish planed, in much less time and with equally permanent accuracy.

The planer is particularly adapted to produce the following classes of work with extreme accuracy: plane surfaces, parallel plane surfaces, parallel surfaces an exact distance apart, two plane surfaces at right angles, as at the edge of a cube,

three plane surfaces at right angles, as at the corner of a cube, parallel surfaces each at right angles to a third surface and an exact distance apart, plane surfaces meeting at an exact angle, as in the case of vees and dovetails, and pairs of surfaces having exact angular relation to each other and with the lines of intersection an exact distance apart, as in paired vees or dovetails. All machine construction depends for its accuracy and rigidity upon fits between such surfaces, and much time and money are expended yearly in filing, scraping, lapping, or otherwise fitting inaccurate work of this nature. As an example of the saving which may be made because of the inherent accuracy of the planer is a 60 × 48-in. planer which has been used for more than ten years in planing steel, usually using a 50-hp motor to capacity. Neither the vees of the table nor the ways of the bed were ever scraped, but are in the same condition in which they came from the planer. The tool marks on the ways of the bed are plainly visible on every square inch of all four surfaces, and there are no bright spots. Most mechanics would consider it necessary to spend many days in scraping such surfaces to a bearing.

FINISH

In the matter of finish, the milling machine has a number of defects. A slabbing mill will produce revolution marks, and if the cutting edges encounter a sand inclusion, there will be a defective line in the work. The planer tool never produces revolution marks, and if the edge of the tool is nicked, it is an easy matter to replace it with a perfect tool, pick up the cut, and go on with the work. Replacing and resetting a large slabbing cutter is much more difficult, and takes more time.

In the case of a face mill, the finish produced on cast iron is invariably inferior to that produced by a planer, since it is marred by ugly circular scratches. Tungsten-carbide face-mill cutters usually produce a very smooth and shiny finish, but the difficulty of matching cuts is considerable, and finish is limited to a surface not wider than the cutter if the matching of cuts is essential to good appearance. Such surfaces are not readily scraped, nor do they present a good foundation for spotting, which is the usually accepted ornamental finish for fine cast-iron work. On the other hand, a planed surface offers an excellent foundation for scraping or spotting whenever either operation is necessary. If a finished surface is to be painted, there is nothing to choose between a milled and a planed surface.

The grade of finish of flat bearing surfaces which rub together is exceedingly important in many kinds of work. If two pieces improperly finished are rubbed together until a good bearing is obtained by wear, a considerable amount of metal is lost, and the surfaces may be seriously damaged in the process. If an attempt is made to bring the surfaces to a good bearing by scraping, or otherwise hand finishing, the accuracy of the parts is impaired. Consequently, there is a great advantage in the rigidity, accuracy, and length of useful life of a machine when its flat bearing surfaces have been planed. The milling of bearing surfaces and subsequent finishing by hand scraping are rightly regarded by most machine-tool builders as inferior workmanship. Machines so made have less economic value than machines having planed bearing surfaces.

In the case of steel surfaces, it is customary to plane such surfaces with a fine feed when a good finish is desired. However, the finished surface produced in this manner is not satisfactory as a bearing, and must be either ground or scraped if it is to be used for such a purpose. Where an unpainted steel surface is to be exposed, slab milling will produce a fairly good finish, although the revolution marks may often be objectionable. Such a surface is not accurate enough to serve as a bearing, and must be ground or scraped before it is satisfactory. Very fine feeds and high speeds produce a good finish on steel when carefully ground tantalum-carbide cutters are used. Face mills do not usually produce a very good finish in steel, leaving circular scratches due to tearing of the metal or the dragging of chips over freshly cut surfaces.

Under proper conditions, using a suitable lubricant, it is possible to plane steel with a wide tool and coarse feed, in the same manner as cast iron is finished, leaving a smooth, glassy surface which is very much superior in accuracy and finish to any surface which can be produced by the methods usually employed in either milling or planing. Such surfaces make excellent bearing surfaces, require no scraping, and permit the use of built-up sections with steel bearing surfaces welded in place, instead of cast-iron bearing surfaces bolted in place.

In the field of formed work where the quantity of work to be produced is sufficient to warrant the making of a form cutter, the milling machine is superior to the planer, especially on steel. If the quantity of work is only sufficient to justify a fly cutter, a lower production time can be obtained by setting up the same job on a planer, and using a form tool suitable for bolting to the apron or clapper block of the planer.

THE "MASS-PRODUCTION" APPEAL

Due to the fact that certain outstanding industries lend themselves to mass production, there is at present a tendency for the designer and the production engineer to become mass-production-minded, and to bring into a shop having a limited production, and even into a jobbing shop, the same type of design and the production methods which are successful in turning out automobile, typewriter, and adding-machine parts, in quantities of hundreds of thousands or even of millions per year. To a man having the mass-production mind, whether he be a designer, a production engineer, or a shop superintendent, none of the general-purpose tools, such as the planer or engine lathe, has much appeal, and the more easily a general-purpose tool can, by special equipment and method of operation, be made like the special tools successfully employed in mass production, the greater its appeal. Hence, the vogue of the milling machine and the turret lathe in fields where they are not economically justified. In most shops, pieces are produced one at a time, or in lots of five or twenty rather than in hundreds of thousands, and we are less interested in seconds per piece than in quality of work and in minimum overall cost of production over a period of years.

When both the production engineering department and the design department are milling-machine-minded, as is often the case, parts are designed so that they can be milled when it might be better to plane them, and extra operations are performed in order to secure the necessary accuracy or finish. We often find that milling machines are provided with every facility for doing the best and the most work of which they are capable, while in the same plant the planer is, figuratively speaking, a red-headed stepchild, which receives no intelligent supervision, which has only a meager equipment of tools and fixtures, and to which are assigned only those jobs which cannot possibly be milled.

Because some forms of milling machines are preferred for mass production, many shop executives think that the planer requires an excessive amount of time on most jobs. Sometimes this is true, but investigations will often show that the excessive time taken on the average planer job is not due to any lack of capacity or ability on the part of a modern planer to perform the work in a reasonable time and in a satisfactory manner, but to the fact that the particular planer used is of obsolete design, is badly worn, or is not provided with the

proper equipment. Quite often the reason lies in the fact that the particular job was designed to be done on a milling machine instead of on a planer, when slight changes or even improvements in the design would greatly reduce the time required by the planer.

The mere fact that a job can be done in less floor-to-floor time on a milling machine than on a planer is not necessarily evidence that the milling machine is the better tool for the job. If the work is planed, it may be so much more accurate and so much better finished that a great deal of time is saved in the scraper room, the assembly department, and on the erecting floor. The true test is not the cost of the operation, but the cost of the product, and this cost includes the items of tooling, production engineering, fitting, erecting, and the burden of idle time of the tool due to limited production, as well as those items of cost more usually considered when choosing equipment.

THE MILLING PLANER

Every open-minded shop man who has studied the subject will admit that in many cases it is very difficult to determine whether a planer or miller of a given size should be installed in a shop doing a variety of work. Not only is this true, but on a single job there may be one class of surfaces which should be planed because of requirements of accuracy and finish, a second class of surfaces which must be planed because location makes it impossible to mill them, a third class of surfaces which should be milled for economic reasons, a fourth class of surfaces which cannot be planed, but which can be cross-milled, and in addition there may be a few holes to be drilled or bored in accurate relation to the planed or milled surfaces. Quite often all of these operations could be performed to great advantage and at a minimum cost in one set-up, were a suitable machine available for doing the work. The obvious solution of the executive's problem of what machine to install and the production engineer's problem of how best to machine the work, is to provide a machine which will do both planing and milling. I do not mean that a planer should be provided with a milling attachment, but rather that a new design is desirable, which will, as far as possible, combine the abilities, conveniences, and advantages of both the planer and the planer-type milling machine. Such a machine should, and can, have the ease of control and the versatility of the planer, without sacrificing the advantages of the milling machine as a production tool. In addition, it may combine some of the advantages of the radial drill, the jig borer, and the horizontal boring machine.

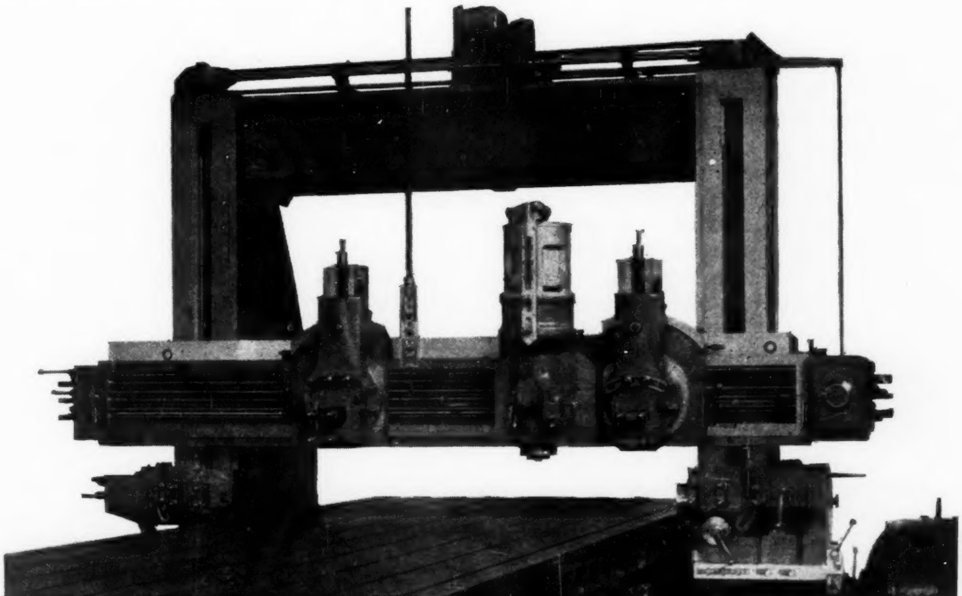
Obviously, such a machine will be somewhat more expensive than a planer or a milling machine capable of operating upon work of the same size. However, it will have practically all the engineering and operative advantages which inhere in either the planer or the milling machine, and some of those which inhere in the other three machines. It will be able to mill those surfaces which should be milled for economic reasons and to plane those surfaces which can be planed to best advantage; and the advantages of both methods of machining may be obtained in one set-up.

The milling planer, when properly designed, will not only combine the accuracy and versatility of the planer with the productive capacity of the milling machine, but is in reality a new machine tool, since it enables the production engineer to perform operations in an order hitherto impossible, combining planing, milling, drilling, and boring operations in one set-up, in such a way as to produce a piece having maximum accuracy at a minimum cost.

Another reason why it deserves to be called a new machine tool is that it makes products of new design economically possible. It enables the designing engineer to produce parts which can be machined to advantage in one set-up, without fixtures, instead of using two or three set-ups on different tools, with possibly one or two heavy and expensive jigs or fixtures to assure the necessary accuracy in the relative location of the several surfaces machined in the different set-ups. Such a machine allows the designer a much greater latitude in attacking his problem, particularly in the case of jobbing work and special machine parts, thus effecting savings in the cost of designing, as well as reducing shop costs on such parts.

The milling planer enables the executive in charge of the purchase of equipment to avoid the problem of whether he shall sacrifice the advantages of the planer for some types of his work or the advantages of the milling machine for other types of his work, and enables the shop executive to route his work with a minimum of trouble and lost time in transferring work from one machine to another.

Planers, milling planers, and milling machines should all find a place in most shops of any size. Each has its special advantages and limitations. These advantages and limitations merit careful and unbiased study by all who have to do with such tools and the work done by them, from the engineers who design the product which they machine, to the executives who purchase them and the shop men who are responsible for their performance and efficiency.



MILLING PLANER WITH TWO MILLING HEADS AND FOUR PLANER HEADS

The CASE *for* MILLING

A Machine-Tool Engineer Looks at the Economics of Milling Versus Planing

By R. E. W. HARRISON[1]

IN TIMES of normal production, the problem—to mill or to plane—is a common one that requires a suitable basis of comparison. In view of the fact that all machine-shop operations are conducted with the primary object of earning a profit, it would seem logical to select as a basis of comparison a formula resulting in an answer in dollars and cents. The object of this paper is to present a method of comparison that will assist the executive, when confronted with this problem, to make a decision that will represent the soundest economics.

BASIC CONSIDERATIONS

When the problem with which we are concerned arises there are many questions which should first be answered, as follows:

(1) Is it desired to produce the piece at the lowest possible ultimate cost, irrespective of past practises?

(2) Will the market for this particular product yield a selling price, in face of existing and anticipated competition, which will permit a production cost other than the lowest attainable with the most efficient machine-tool equipment?

(3) Is there any basic, unchangeable, or physical characteristic of design of the piece to be machined which prevents it from being handled by one or the other type of machine? "Design" in this case covers metallurgical specifications involving machinability as well as the shape of piece.

Assuming that the answers to these questions condense into the statement that the work must be produced at the lowest ultimate cost, and that there are no physical handicaps which control the selection of the machining process, the next step in the analysis of the problem is to secure those additional items of detailed information which are required to lead to a logical conclusion. These items are as follows:

(*a*) Size and weight of individual piece, and lot sizes
(*b*) Type of work-handling facilities (loading, unloading, and storage), actual or projected
(*c*) Desired and present rate of production specified as number of pieces per hour, day, week, or year
(*d*) If the item of work now under consideration is being performed on an existing machine which is to form the pivotal point of the comparison, the present and proposed work cycles should be broken down into loading, actual cutting, unloading, and change-over time
(*e*) The overhead or burden allocation scheme in the particular plant under consideration
(*f*) Operators' rates of pay
(*g*) Rate of tool expense, which will include first cost plus maintenance cost minus salvage value
(*h*) Actual or anticipated cost of maintaining machine tools in 100 per cent productivity
(*i*) Tolerances on dimensions of work to be performed
(*j*) Desired finishes on work to be performed
(*k*) Amount of stock to be removed
(*l*) Material specification involving machinability
(*m*) Available power (check to ensure adequacy and cost)
(*n*) Probable future products (involving permanency of value of investment).

The author has deliberately introduced the elements of the problem as outlined above in the belief that it is logical to discuss the basic factors first, and later to elaborate on the details of manufacturing technique applying to each type of machine.

As these individual items are discussed, the lines along which their values are apportioned become plain, and the items take their respective places in the final picture.

It should be borne in mind that the final picture represents a total return on investment and that there are different types of investment. In some businesses the relatively short-term investment is necessary; short term in this case being interpreted as any period up to five years. The modern automobile shop finds that its manufacturing technique and work accommodation requirements change so frequently and completely within a period of five years that it is wise, as in the case of practically all rapidly changing domestic products produced on mass-production lines, for the machine-tool equipment to be bought on the assumption that it will earn the return of the capital investment plus a satisfactory margin of profit, in a period up to five years maximum. On the other hand, in many businesses where the products have not changed in type, size, and general characteristics, and are unlikely to change materially over a period of ten years, the ten-year return basis is a logical line of procedure.

WORK-HANDLING FACILITIES

On small work, the slower table motion of the milling machine often permits work to be loaded and unloaded while the cutting tools are functioning, thereby reducing idle or non-cutting time to a minimum, particularly on manufacturing operations. In some instances the ratio of cutting to idle time will reach 9 to 1, whereas in normal jobbing-shop operations the ratio is generally 3 to 7.

On medium and large-size work, work-handling facilities of milling machines and planers are approximately equal, although fixture development for milling machines has reached a much higher level of efficiency.

The table of the planer must be stopped while work is loaded and unloaded. The use of duplex tables is not unknown, but on account of cost and additional floor space, this arrangement is rarely used.

Work-handling opportunities are approximately equal, as regards accessibility.

On account of the slower table traverse, it is often easier to inspect the work during actual machining on the milling machine than on the planer.

[1] Mechanical Engineer. Mem. A.S.M.E.

Part of a Symposium on Planing Versus Milling, contributed by the Machine Shop Practice Division for presentation at the Annual Meeting, New York, N. Y., Dec. 4 to 8, 1933, of The American Society of Mechanical Engineers.

VERSATILITY

The modern fully equipped milling machine is much more versatile than the planer. The numerous attachments and the types and varieties of cutters which can be applied permit a wider range of machining operations than is possible on the planer.

It is frequently possible to bore holes and slot complicated designs at one chucking of the work in a milling machine. Furthermore, it is a relatively easy matter to equip the modern milling machine with a planing-tool attachment which permits the planing of otherwise inaccessible facings without resetting.

ACCURACY

There is nothing to choose between the accuracy obtainable on modern planing and milling machines, whether the machines be of large or small capacity. It is customary to build both types of machines to the accepted limits of accuracy and tolerances common to the machine-tool trade, and while these tolerances naturally set the limits of accuracy to which the work can be produced, the accuracy-producing qualities of both milling machines and planers become a reflection of the efficiency of the set-up and the tool-grinding operations. Given correctly designed machine tools on proper foundations, with alignments systematically checked at given periods, there is no reason why work of a similar nature cannot be produced within equal limits of accuracy on either type of machine.

FINISH ON MACHINED SURFACE

The commonly accepted practise, in milling operations, is to rough and finish with the same cutter, the speed of rotation being increased and the depth of cut reduced to a minimum when finishing. The milling cutter exercises a tendency to close up the pores of the material being worked on, whereas the planer tool has a tendency to pluck particles from the face of the machined surface, sometimes making it necessary to reject cast-iron parts because of porosity.

On the planing machine it is always necessary to change tools when switching from the roughing to the finishing operation. Few plants provide adequate facilities for grinding planer tools; hence the quality of the finished product from the planer is frequently in the more or less skilled hands of the operator who must grind his finishing tool by hand to secure flatness, a somewhat hazardous process.

HAND FINISHING AFTER MACHINING

For a given job the amount of hand correction depends on (1) the accuracy with which the work has been machined, and (2) the depth of the scratches produced by the cutting tool. With a correctly ground milling cutter, a machine-tool slide of cast iron can be scraped to an acceptable finish in approximately one-half the time required to do the same work when the same slide has been planed. This is due to the shallowness of finish defects.

Both milling machines and planers are capable of producing work of such a degree of accuracy and finish that the components can be assembled with practically no hand correction.

As is the case in all machine-shop operations, there is a definite relationship between finish and ultimate accuracy. The finish produced by the milling machine reduces the extent of the inevitable initial wear and this permits a loaded slide which has not been scraped to assume an 85-per cent bearing in about one-half the time required by a planed slide under similar conditions.

While it is true that forced lubrication has done much to prolong the time of initial wear, the fact remains, and must always be faced, that there occurs a time in the life of all machines when the slides are overloaded, and it is during a peak load of this nature that the machine with slides most nearly approaching the true plane has the best chance of emerging from the ordeal with undamaged surfaces and unimpaired ability to produce accurate work.

The earlier reference in this paper to the time taken to scrape a milled, as against a planed, slide, due to the smaller amount of metal to be removed by the scraper in the case of the milled job, indicates the advantages of the milling process. The reasons accounting for this situation can be summed up as cutter accuracy and generative cutting action. It is always necessary to grind a milling cutter by a precise process on a machine built to extremely close limits of accuracy; the planer tool is seldom ground under these conditions.

Admitting that both milling and planing tools have their respective inaccuracies, the rotary coverage of the milling cutter is considerably more generative in its action than is the straight-line copying principle on which the planer depends.

MACHINABILITY

Defining machinability as the measure of responsiveness of a piece of work to a shaping process by a metal-cutting tool-steel dies have recently been successfully milled after rejection by the planing machine.

AVAILABLE RATES OF METAL REMOVAL

Measured in terms of cubic inches of material removed per horsepower applied, there appears to be little to choose between the processes of milling and planing. There is no royal road to metal removal by any of the machining processes (rate is always controlled by horsepower), and although the milling cutter employs a multiplicity of cutting tools, the horsepower consumed is dependent on the chip load of each tooth in the cutters, just as is the case with the planing machine.

There is, of course, a decided advantage in the case of the milling machine in that there is no idle return stroke. Furthermore, by using a cam-controlled variable feed rate, it is an easy matter to keep the cutter working up to its maximum capacity, irrespective of the varying area of the cut. In other words, if a combined machine, job, and milling cutter are capable of operating at, say 15 hp, and this particular combination will stand up indefinitely at a metal-removal rate of 2 cu in. per hp applied, or a total of 30 cu in. per min, the feed rate during the cutting portion of the work cycle can be so controlled that the load on the motor is constant, and the cutting tool operates at a constant 100 per cent efficiency. No such accurate load control can be applied to a reciprocating planer.

On account of the number of cutter heads, and the multiplicity of blades operating in each head, say four heads each employing a cutter with 30 blades, we have 120 cutting tools. Only the applied horsepower limits the rate of metal removal. In such a case it is not unknown to employ usefully more than 100 hp, removing metal at a rate in excess of 300 cu in. per min.

CHANGE-OVER TIME

Accessibility being equal, comparison of change-over time resolves itself into the time of tool changing. Time records indicate that the greater time taken to install the milling cutter offsets the greater frequency with which the planer tool must be withdrawn for regrinding. In jobbing work in small lots, the advantage is with the planer on long narrow strip work. In manufacturing work in larger lots, the advantage is with the milling machine.

FIRST COST IN RELATION TO THE RATE OF PRODUCTION AND TO THE UPKEEP

Unit for unit, the planer and the milling machine of similar capacities have much in common as regards weight, design, and the number of man-hours necessary to produce. It is only in regard to the tool-carrying units that there is any great variation.

On account of the fact that the milling cutter necessitates a revolving spindle with means for driving it at various speeds, the milling machine naturally has a higher first cost. However, this is frequently offset by the fact that milling operations are carried out on shorter machines with proportionately shorter beds and tables. This condition is brought about by the fact that gang operation, as understood in planing practise, is not desirable or necessary when the same piece is milled.

UPKEEP

Experience with upkeep costs over a number of years leads to but one conclusion: Machine maintenance up to a given standard varies in direct proportion to the number of moving parts in the machine, and the capital investment. Hence, assuming that we have the problem of keeping comparable planing and milling machines up to the same standards of accuracy and maximum output, it follows that the milling machine is the more expensive to maintain. Records clearly show, however, that the modern planer and the equally modern milling machine both have a low rate of maintenance as compared with other types of high-production tools, this simply means that safety factors have been purposely made higher in anticipation of the higher loads involved in present-day practise.

The attractiveness of a machine-tool investment can be figured from the equation

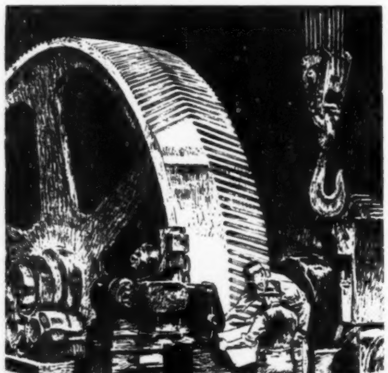
$$\frac{\text{First cost plus maintenance cost in dollars}}{\text{Total units produced over a period of years}} = \text{Unit cost}$$

and it is due to the higher production rate applicable to the milling machine, that this type of investment has found so much favor during the last ten years.

The production rate applicable to milling machines in 93 out of 100 job classifications is definitely higher; the smaller the job the larger the difference. The resulting fraction, although involving a higher investment figure than that applying to the planer (the sum of first cost plus maintenance), represents a saving in manufacturing cost, which makes the investment in first cost plus maintenance a very attractive one.

TOOLING—FIRST COST AND UPKEEP

No review of machine-shop operation costs can be complete without a minute analysis of tooling—first costs and upkeep on cutters against amount of metal removed, measured in terms of cubic inches —qualified by *rate* of metal removal. To quote an accepted analogy, grinding-wheel efficiency was formerly measured in terms of length of life only; today it is realized that total metal-removal capacity qualified by rate is the real criterion, and although the modern grinding wheel is relatively soft and wears away at a much more rapid rate than the older wheels, the ratio of metal removed to wheel wear is infinitely better, and the improved rate of metal removal makes the investment a very much more profitable one than was formerly the case.



Courtesy Mackintosh-Hemphill Co.

ACTUAL TOOLING COST OF REMOVING METAL BY THE MILLING PROCESS

Recent investigations have brought to light some remarkable tooling costs applicable to heavy-duty milling in cast iron of medium hardness. A type "A" milling cutter will remove 6000 cu in. per grind and can be reground 70 times. In view of the fact that a set of blades for this cutter costs the user $20.80, 200 cu in. of metal can be removed for one cent invested in high-speed steel.

With a cutter of type "B" which has an actual metal-removal life of 1,620,000 cu in. per set of blades costing the user $28, a volume of 578 cu in. of cast iron can be removed for one cent invested in high-speed steel.

These are conservative figures and represent cutter costs only. They do not include such items as hourly rate charged against the machine. Judged as an implement for removing metal, the modern milling cutter is capable of a very economical performance.

Great care is exercised in analyzing milling cutter costs. It is sometimes difficult to obtain exact data on which to make the analysis, but unless the choice of process is guided by facts, the result is a guess, and is as likely to be wrong as right.

No doubt similar data can be made available in respect to first cost and upkeep on planer tools. The author has not seen the tool costs of planing operations put under the microscope by the planer makers, but his observation, as a user, of the costs of this type of machine is that they are considerably higher than is generally thought to be the case when *all* the factors are taken into account.

Broadly speaking, however, neither the planer nor the milling machine can, or does, rely on relative tooling costs to establish profit earning efficiency on any one job or range of work. Machine-hour rates are relatively of so much greater moment that the final result is practically always controlled by the total number of man-machine-hours necessary to produce a given result.

CONCLUSION

As stated in the introduction to this paper, the final answer, to stand the acid test of economic acceptability, must be in dollars and cents. On the basis of the factors outlined in this paper, a balance sheet can be prepared which will give the true picture. This picture varies with every given set of conditions, and it would be absurd to make a blanket statement that one or the other process is a cure-all. Such factors as overhead cost, replacement policy desired rate of return on investment, all varying with the individual concern, exercise their influence on the final result.

The manufacturers of both types of machines realize that no amount of argument or persuasion can alter the facts which go to make up the items of the balance sheet, and it is on the orderly presentation of this factual evidence that the makers rest their case.

HEAT EFFECTS *in* LUBRICATING FILMS

By ALBERT KINGSBURY[1]

I—THEORETICAL

IN THE present discussion, it is assumed that the film thickness is small compared to the radius of the journal and that the surfaces may therefore be considered as plane; that there is no discontinuity of temperature between the boundary layers of the film and the surfaces of the metals; that the flow is laminar or streamline in character, and that the conduction of heat in the oil is not directly affected by the motion.

The three following equations are fundamental:[2]

$$\mu = f(\theta) \qquad [1]$$

$$s = \mu \frac{du}{dy} \qquad [2]$$

$$H = s(u - u_0) = -k \frac{d\theta}{dy} \qquad [3]$$

Complete formal reduction of these equations is not readily effected by ordinary methods. The greatest of the difficulties is due to the fact that μ as a function of θ can only be expressed by one of a number of empirical forms, none of the more closely approximate forms being readily usable in the required integrations. A further difficulty arises if k is considered as dependent upon θ.

These obstacles may be surmounted in any stated case by the method described in this paper and called the "graphical method," although it may be carried out entirely by numerical calculation if μ and k are known at small temperature intervals. The solution may be made as accurate as desired; more accurate, in fact, than the degree of precision usually attained in experimental determinations of μ and particularly of k.

For use in the development of the graphical method, the following analytical forms are derived:

From [2] and [3], integrating between the extreme limits,

$$\int_0^U (u - u_0)du = -\int_{\theta_2}^{\theta_1} \frac{k}{\mu} d\theta \qquad [4]$$

whence

$$u_0 = \frac{U}{2} + \frac{1}{U}\int_{\theta_2}^{\theta_1} \frac{k}{\mu} d\theta \qquad [5]$$

Using the limits 0 and θ_2, u and θ, leads to

$$u = u_0 \pm \sqrt{u_0^2 - 2\int_{\theta_2}^{\theta} \frac{k}{\mu} d\theta} \qquad [6]$$

From [2],

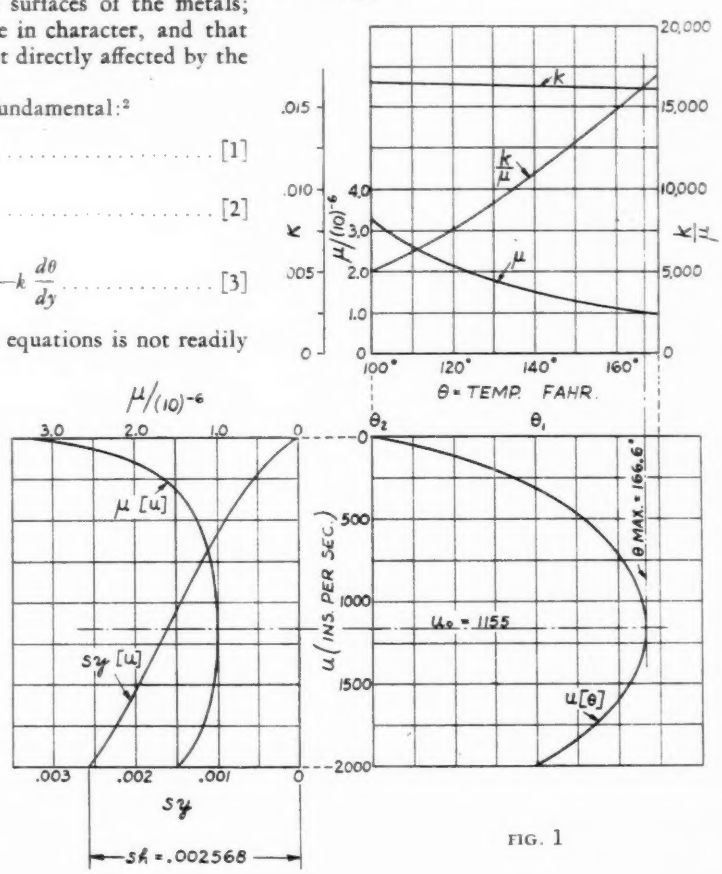


FIG. 1

$$sy = \int_0^u \mu du \qquad [7]$$

$$sh = \int_0^U \mu du \qquad [8]$$

whence y/h follows from the ratio of the indicated integrals.

THE GRAPHICAL METHOD

The application of the above equations may be shown by solving a particular problem by the graphical method, with the following data, the basic units being inches, pounds, seconds, degrees F.

Surface speed of the journal, $U = 2000$

Temperature of the journal surface, $\theta_1 = 140$

Temperature of the bearing surface, $\theta_2 = 100$

Conductivity of the oil, $k = 0.01688[1 - 0.0003(\theta - 32)]$

Viscosity of the oil, $\mu = 0.1561/\theta^{2.338}$

Required, to find the shearing stress s, and to plot, for all values of y/h, the velocity u, the temperature θ, and the relative rates of shear.

Referring to Fig. 1: With the linear scale of temperatures as axis of abscissas, lay off as ordinates, to suitable scales, the values of μ, k, and k/μ. By Equation [5] find the value of u_0, the indicated integral being found from the area, to scale, under the k/μ-curve between the ordinates at θ_2 and θ_1; the resulting value is $u_0 = 1155$. Then choosing any temperature θ, find the corresponding value of u by Equation [6], the integral term now being the area under the k/μ-curve between

[1] President, Kingsbury Machine Works, Inc., Philadelphia, Pa. Mem. A.S.M.E.

[2] For meaning of symbols used, see "Notation" at end of paper.

Contributed by the Special Research Committee on Lubrication for presentation at the Annual Meeting, New York, N. Y., Dec. 4 to 8, 1933, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

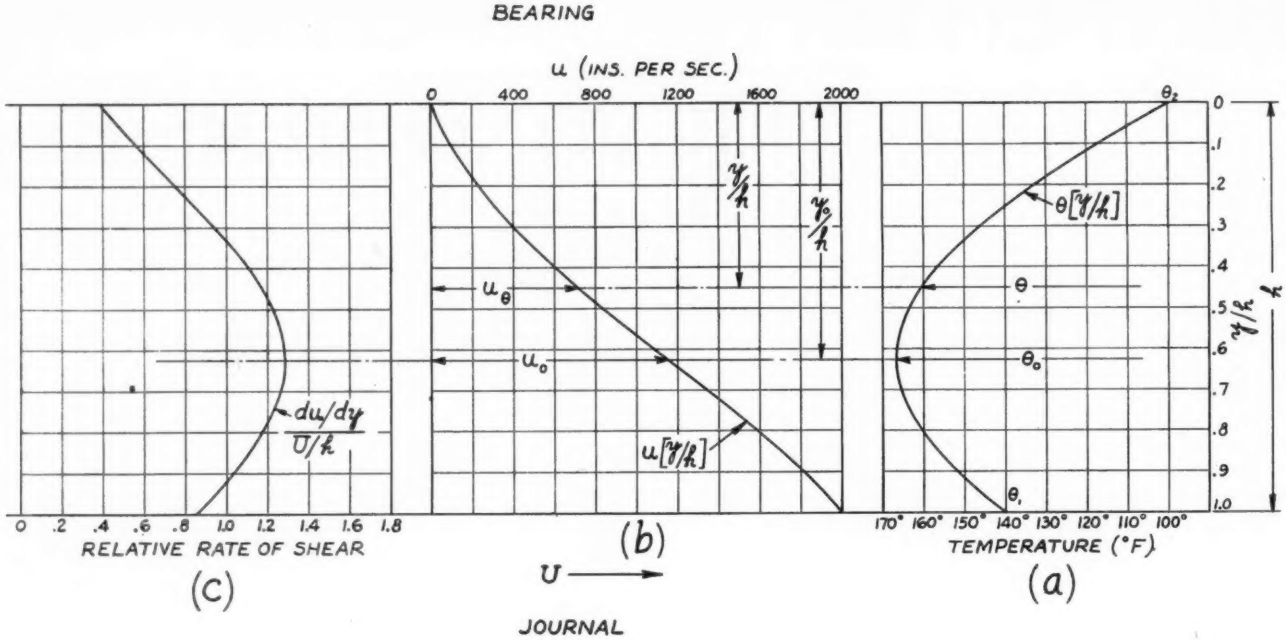


FIG. 2

θ_2 and θ. Having thus found a sufficient number of corresponding values of u and θ, draw the complete $u[\theta]$-curve, the scale for u being linear. It will be noted that both u and θ are independent of the absolute value of h. Next draw the $\mu[u]$-curve through points determined by the values of μ corresponding to values of u (and hence of θ); it shows a minimum value of μ at the value of u where θ is a maximum, as should be expected. The curve $sy[u]$ is next drawn, Equation [7]; the integrals are now the areas on the right of the $\mu[u]$-curve, located between the horizontals $u = 0$ and $u = u$.

The maximum value of sy is 0.002568, occurring where $u = 2000$, $y = h$; thus if $h = 0.001$, $s = 2.568$ lb per sq in.; whereas if s were calculated from the viscosity at the temperature of the bearing alone, it would be given by $s = \mu U/h = 6.584$ lb per sq in.; the true value is but 39 per cent of this. The load that can be borne by a bearing being roughly proportional to the shearing stress that can be maintained, it is obvious that the internal heating of the film is an important factor in limiting the possible load.

Thus far, the quantities are not shown with reference to a linear scale of y or of y/h, but the $sy[u]$-curve furnishes the necessary means for the conversion; by the ratios $sy/sh = y/h$ the corresponding values of θ and of u are found by reference to the curves in Fig. 1 and are shown in Fig. 2 (*a*) and Fig. 2 (*b*), respectively. In Fig. 2 (*c*), the rates of shear du/dy are compared with the mean rate U/h, which is the same as if the temperature were uniform; with the value of sh already found, the relative rate is, from Equation [2], $(du/dy)/(U/h) = sh/\mu U$. The maximum rate is 1.286 times the mean, and 3.3 times the minimum.

From Equation [3] the heat per square inch and per second going to the journal is given by $H_1 = s(U - u_0)$ and that to the bearing by $H_2 = su_0$, respectively 42.3 and 57.7 per cent of the power sU per square inch.

II—EXPERIMENTAL

It would be impracticable to verify the preceding theory in all respects by direct experiment, owing to the thinness of lubricating films. It is, however, possible to observe one of the external manifestations of the internal heating of such films, namely, the reduction of the shearing stress due to the reduced viscosity. This is the basis of the following experiments.

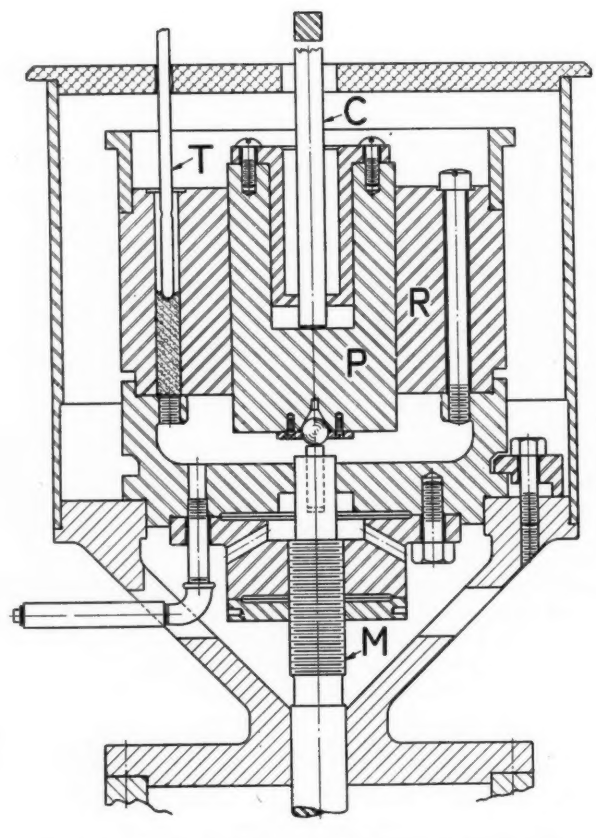


FIG. 3 VERTICAL SECTION OF TAPERED-PLUG VISCOMETER

DESCRIPTION OF VISCOMETER

The tests were made by means of an "absolute" rotational viscometer, shown in axial section in Fig. 3.

A ring *R* and a plug *P*, both of normalized 0.85 per cent carbon crucible steel, are fitted closely by grinding together, the fitted surfaces being slightly conical, with a taper of about 1:100 referred to the radius. The plug has a ball pivot resting on the micrometer screw *M*, by means of which the plug may be adjusted vertically to give any desired small clearance between the fitted surfaces; this clearance space alone may be filled with oil, forming the film to be tested, or the device may be entirely submerged in oil. The plug is rotated by a driving spindle through the flexible coupling *C*, and is held concentric with the bore of the ring by the action of the test oil itself in the clearance space; thus no centering bearings are required, and the torque required to hold the ring against rotation is equal to that due to the shearing of the oil film, plus a small torque due to the "end effects" and the pivot friction. The latter torque is ordinarily negligible, being so small in comparison with that due to the film as to be difficult of detection. A thermometer *T* with the bulb immersed in mercury gives a fair indication of the film temperature when the speed of rotation is low. For tests at temperatures above that of the atmosphere, the entire device is enclosed in an electrically heated casing, not shown in the figure. With careful manipulation and with corrections for temperature and for curvature,[3] it is estimated that the error in measuring the viscosity of an oil should not exceed ±0.2 per cent.

The dimensions of the ring are: outside diameter, 7 in.; bore (larger end), 3.0413 in., (smaller end), 2.9669 in.; height, 3.7503 in.; taper per inch (on the radius), 0.009919 in.

A precisely similar device was made in 1901, having one-third of the linear dimensions of the present device, and was used in the machine described by the author.[4] It gave some indications of the kind now under consideration, but because the machine was belt-driven and therefore the instantaneous rotational speed was difficult to determine with precision, the subject was not pursued further at that time.

The present testing machine, follows the general principles of the 1901 machine, but has the important improvement of chain and change-gear transmission from a synchronous motor rated at $7^1/_2$ hp, 1200 rpm. The machine is also provided with friction clutches, whereby the spindle may be quickly started or stopped. The motor receives current from the city mains, in which the frequency is very closely regulated to 60 cycles per sec, and therefore the calculated spindle speed at the machine can be taken as correct. In the parts used for journal-bearing tests (not shown in the photograph, being replaced by the viscometer described above) the load is hydraulically applied by means of a hand pump incorporated with the suspended parts, and may be as great as 100,000 lb.

EXPERIMENTAL PROGRAM

The successive steps in the experiments with the tapered-plug viscometer, made with a view to obtaining some degree of physical support for the foregoing theory, were briefly as follows:

(*a*) The parts were filled with the test oil, taking care to exclude air, brought to the desired uniform temperature, and adjusted to the desired film thickness

(*b*) A short preliminary run was made at low speed, to insure uniform distribution of the oil in the film

(*c*) The clutch being closed as quickly as possible, there was an acceleration period of about 0.1 sec, leading immediately into

(*d*) A run of about 1 sec at the desired maximum speed

(*e*) During (*c*) and (*d*) a chronographic record was made, showing the total revolutions of the plug at intervals of $^1/_{120}$ sec

(*f*) At a pre-determined time *t* varying from about 0.3 to about 0.7 sec from the beginning of (*c*) in the different tests, the torque was recorded by an electrically operated marker

(*g*) The instantaneous maximum temperature within the film at the time *t* and the instantaneous torque were calculated from the preceding theory, and the latter was compared with the observed torque as a partial check on the theory.

In all calculations, the units employed were: of length, the inch; of force, the pound; of work and of heat, the inch-pound; of time, the second; and of temperature, the degree Fahrenheit.

Regarding item (*f*): Because of the low frequency of the damped oscillation of the suspended parts (about 1.7 cycles per second, $\log_{10}$ dec. = 0.4) the variable torque could not be measured continuously; hence for measurement at the time *t*, the torque spring was pre-strained to slightly less than the expected torque, the motion of the pointer being closely limited by fixed stops, and the reading was accepted only when the record showed that the pointer was free of both stops.

The processes involved in (*g*) required first the calculation of the temperature at the metallic surfaces, as a base temperature from which to calculate the temperatures θ within the oil film. In doing this, it was assumed that all the work done in shearing the film was absorbed by the metals, since the heat capacity of the film itself is small; for example, in test 5 of Table 1, if the walls were non-conducting, the film temperature would rise at the initial rate of about 1500 deg F per sec, at full speed.

The temperature rise at the walls was calculated by the known formula[5]

$$v = \frac{1}{2a\sqrt{\pi}}\int_0^t e^{\frac{-x^2}{4a^2(t-\tau)}}(t-\tau)^{-\frac{1}{2}}\varphi(\tau)d\tau$$

in which v is the temperature rise at a point at a distance x below the surface in the time t; τ is any time between 0 and t, $\varphi(\tau)$ is the variable instantaneous power per unit of area, the unit of work being that required to raise the temperature of unit volume of steel 1 deg F (304.2 inch-lb), and a^2 is the diffusivity of the steel, here taken as 0.0199. The diffusivity was not found by direct test, but was derived from the data in the Smithsonian Physical Tables, Table 237; in cgs units, 0.173 for iron, 0.121 for 1-per cent carbon steel; by linear interpolation, 0.1288 for 0.85-per cent carbon steel. Diffusivity having dimensions L^2T^{-1}, the conversion factor is $1/2.54^2$, giving $a^2 = 0.0199$, $a = 0.1411$.

Strictly, the formula relates to a variable source of heat at a plane in an infinite solid, but is taken as closely approximating the conditions of the present problem. While it cannot be evaluated directly for the required conditions $\tau = t$ and $x = 0$, the value may be approached as closely as desired by one of several methods which need not be described here.

In calculating v, the values of $\varphi(\tau)$ were calculated from the

[3] "A Monograph of Viscometry," by G. Barr, Oxford University Press (1931), p. 222.

[4] "A New Oil-Testing Machine," by A. Kingsbury, Trans. A.S.M.E., vol. (1903), pp. 143 to 160.

[5] "Fourier's Series," by Byerly, Ginn and Company, Boston, p. 94 (5).

TABLE 1 TEST RESULTS ON TWO OILS DETERMINED BY TAPERED-PLUG V[illegible]ETER

	No. 4 Mineral Oil,[a] 0.88 sp gr				Olive Oil[b]			
Test No.	1	2	3	4	5	6	7	8
Rpm	1540	910	1540	910	1540	1540	910	910
Surface speed	242.3	143.2	242.3	143.2	242.3	242.3	143.2	143.2
Initial temp., F	73	73	86	86	73	86	73	86
Initial viscosity $\times 10^6$	20.49	20.49	12.83	12.83	10.79	7.891	10.79	7.891
Film thickness	0.004242	0.002527	0.002656	0.001604	0.001621	0.001621	0.0009919	0.0009919
t, critical time, sec	0.3917	0.6167	0.4000	0.5917	0.4083	0.3917	0.6250	0.6500
Torque, calculated from initial viscosity	62.21	61.71	62.21	60.88	85.73	62.70	82.79	60.55
Torque observed at time t	48.96	54.32	52.71	55.99	75.58	57.78	76.27	57.61
Calculated temperature rise at walls	1.891	1.555	2.030	1.541	2.853	2.154	2.153	1.646
Calculated max. temp. rise in film above wall temp	6.980	2.895	4.440	1.370	3.450	2.002	1.805	0.723
k, coefficient of conductivity of oil calculated from observed torque	0.01765	0.01625	0.01828	0.0220	0.0205	0.0267	0.0142	0.02667
Mean value of k		0.01855				0.02202		

[a] Viscosity at 100°, 8.162×10^{-6} (0.5629 poise).
[b] Viscosity at 100°, 5.515×10^{-6} (0.3804 poise).

time-speed record, first on the assumption that the viscosity remained constant from the beginning of the time t, then by assuming that the mean viscosity was the same as that indicated by the torque at the time t. The difference between the resulting values v_1 and v_2 was of the order of 0.3 F, the true value lying within this range and nearer the lower value; hence the true value of v was arbitrarily taken as $v = v_2 + (v_1 - v_2)/3$.

Two different oils were used in the experiments, four tests under different conditions being made with each oil. The viscosity-temperature characteristics of both oils were determined by means of the tapered-plug viscometer itself in connection with the tests.

RESULTS OF TESTS

The results of the tests are shown in Table 1. The table is arranged with special reference to the value of the conductivity derived from the observed torque by means of the preceding theory.

The mean value of k thus found for the mineral oil is 4.6 per cent greater than the mean of those found by Smith[6] for two mineral oils of densities 0.94 and 0.852, giving $k = 0.000337$ and 0.000341, respectively, at 86 F, which with the conversion factor 52.26 give a mean of 0.01772 in-lb/(in.) (sec) (deg F).

The mean value of k found for the olive oil is 6.7 per cent greater than that shown in the Smithsonian Tables, 0.000395 cal/(cm) (sec) (deg C) which, with the conversion factor 52.26, gives 0.02064 in-lb/(in.) (sec) (deg F).

The considerable variations in the values of k derived from the single observations of tests 1 to 8 are thought to be due mainly to the small errors in the measurements of the torque, a quantity difficult to measure with precision under the conditions of the tests; but the mean values of k are not unreasonable. An error of one per cent in the observed torque corresponds to an error of about 20 per cent in the value of k calculated from the theory; and conversely, the mean discrepancies of 4.6 and 6.7 per cent between the average values of k and the results of direct tests correspond respectively to mean errors of about 0.23 and 0.34 per cent in the observed values of the torque.

The results of the tests show unmistakable effects of the kind and of the order to be expected from the theory, and although the discrepancies are not inconsiderable, it is thought that the theory is approximately verified within the limits of the experiment.

[6] J. F. D. Smith, *Ind. Eng. Chem.*, vol. 22 (1930), p. 1246.

ACKNOWLEDGEMENTS

The author's thanks are due for the assistance given throughout the work by Mr. S. J. Needs,[7] who conducted all the experimental work and made the incidental calculations; also to Mr. M. D. Hersey,[8] for many helpful suggestions and for reading the manuscript.

NOTATION

θ = temperature at any part of the film
θ_1 = temperature at the surface of the journal
θ_2 = temperature at the surface of the bearing
θ_0 = maximum temperature in the oil
μ = coefficient of viscosity of the oil, dependent upon θ
k = coefficient of thermal conductivity of the oil
h = thickness of the film
y = distance from the surface of the bearing to any point in the film
y_0 = value of y corresponding to θ_0
U = surface speed of the journal, the bearing being stationary
u = velocity in the oil at the distance y from the bearing surface
u_0 = velocity in the oil at y_0, θ_0
H = heat flow per unit area and per unit time, normal to the surfaces, at any value of y
s = shearing stress in the oil due to simple shear, the same at all values of y
a^2 = diffusivity of the metal.

In the numerical work, the units used herein, except as otherwise stated, are: of length, the inch; of force, the pound; of time, the second; of work and of heat, the inch-pound; of temperature, the degree Fahrenheit.

The following factors have been used for converting published data to this system of units:

Quantity	Units	Conversion factor
μ	(dyne)(sec)/cm^2 = (poises)	1.45×10^{-5}
k	(cal)/(cm)(sec)(deg C)	52.26
a^2	cm^2/sec	0.155

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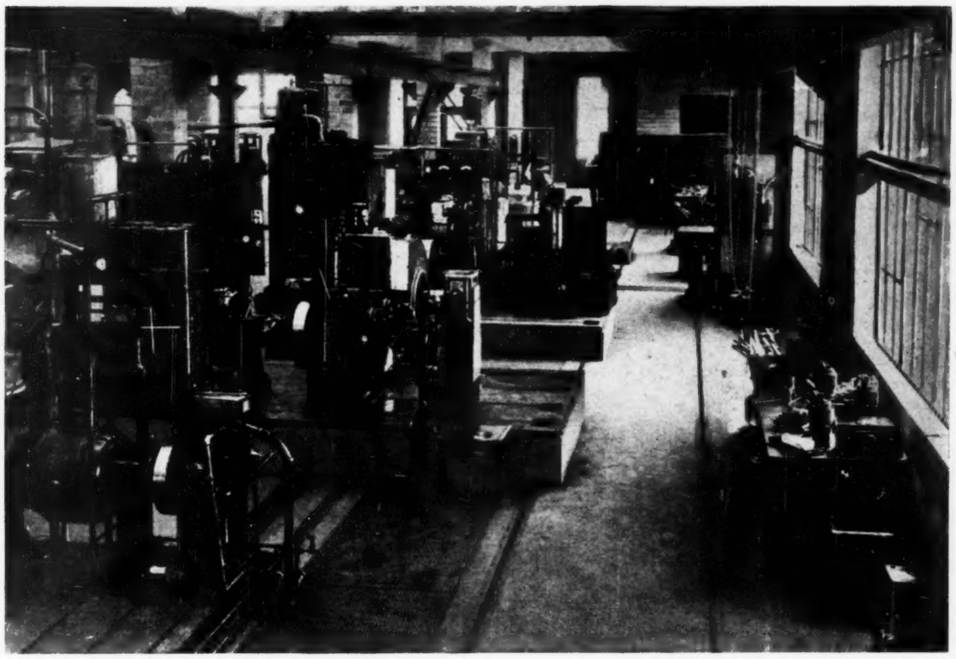
[8] Research and Development Laboratories, Socony-Vacuum Corp., Paulsboro, N. J. Mem. A.S.M.E.

FIG. 1 INTERIOR VIEW OF INTERNAL-COMBUSTION-ENGINE LABORATORY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY



Researches on the INTERNAL-COMBUSTION ENGINE

Equipment and Projects at the Massachusetts Institute of Technology

BY C. F. TAYLOR[1]

THE Internal-Combustion-Engine Laboratory at the Massachusetts Institute of Technology is a one-story structure about 80 by 160 feet (Fig. 1). Since the work in internal-combustion engines at M.I.T. includes undergraduate laboratory instruction, there are a number of engines of representative types coupled to electric dynamometers or to water brakes, and arranged in the usual manner for power and economy tests. Such equipment is segregated on the east side of the building, while the west side is occupied by apparatus designed particularly for research. Installed in this portion of the building, at present, are seven electric cradle dynamometers, ranging in capacity from 10 to 150 hp, each completely equipped with measuring apparatus.

Since the research program calls for work in the fundamentals of the engine cycle, most of it is carried out on single-cylinder engines. Three of the dynamometers carry so-called "universal" crankcases, two of which are of special design (Fig. 2). Such crankcases provide for a high degree of flexibility in the type and size of cylinder which can be installed, and they will accommodate various types of valve gear and auxiliaries. Compression ratio may be varied by adjusting the connecting rod, which has a threaded joint for this purpose (Fig. 3). For overhead-valve cylinders, a special supporting yoke (Fig. 4) is provided, with rocker arms which have an adjustable leverage. On these crankcases, adjustments, in general, must be made while the engine is not operating.

In contrast to the universal crankcases, is the N.A.C.A. universal test engine which has a fixed cylinder design, but which permits of a wide range of adjustment while the engine is in full operation. This engine is equipped with an electrically driven Roots aircraft-type supercharger, which may be used also as an air-meter by disconnecting the driving motor. The supercharger outlet is connected to a large pipe line in the service trench, so that either supercharging, or metered air, is available for use at each of the other dynamometers.

Mounted on one of the small dynamometers is a Cooperative Fuel Research engine which is used for knock-rating work as well as for other investigations. On another small dynamometer is mounted an L-head engine which lends itself readily to observations and measurements of the combustion flame, on account of the flat combustion-chamber top in which windows may be installed.

In addition to the dynamometer equipment there is a small high-speed wind tunnel for research in heat transfer from various kinds of surfaces to air at high velocity.

[1] Professor of Automotive Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

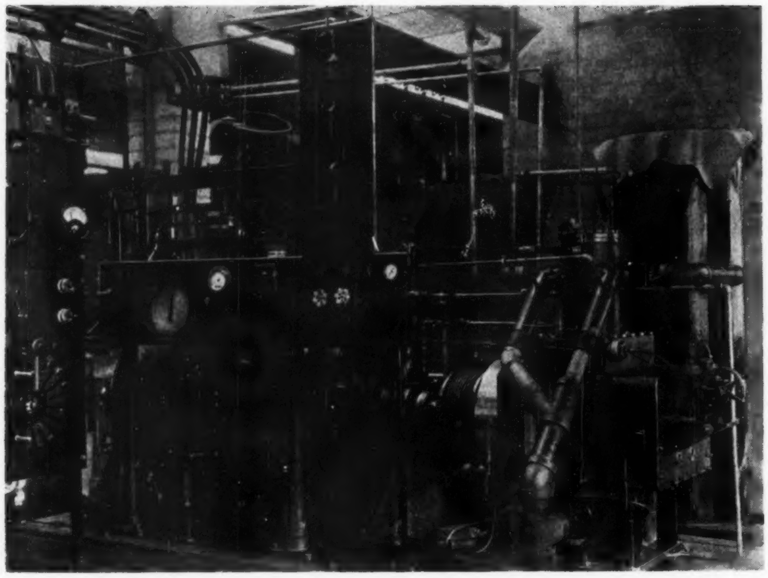


FIG. 2 FUEL-INJECTION RESEARCH ENGINE ON UNIVERSAL CRANKCASE

FUEL-INJECTION SYSTEMS

A normal carbureter is not only very sensitive to changes in atmospheric pressure and temperature, but the manifold-carbureter combination gives a variation in fuel charge from stroke to stroke, even on a single-cylinder engine. In order to avoid such variations in fuel quantity and at the same time to be able to keep it accurately under control, the ordinary form of carbureter has, for most laboratory purposes, been discarded in favor of a Diesel-type fuel-metering pump which injects a finely atomized jet of fuel into the intake pipe. A very simple type of injection nozzle, which handles this type of injection extremely well, has been developed.[2]

ENGINE INDICATORS

After extensive experience with the usual types of high-speed engine indicators, the laboratory has, to a large extent, been forced to develop its own indicating equipment. The balanced-diaphragm indicator which has been developed here[3] and is now giving satisfactory results, combines the simplicity of the Bureau of Standards diaphragm pressure element, together with the automatic recording feature of the R.A.E. indicator. This indicator has proved very satisfactory for all uses where the averaging type is desired.

For certain purposes the averaging type of indicator is not satisfactory, and a record of a single cycle is desirable. In this case a General Motors carbon-pile element has been used. An amplifier has been found necessary in order to cut down to a minimum the amount of current passing through the pile and the bridge circuit. A special amplifier with straight-line characteristics up to 30 ma, has been built. This instrument is useful for other purposes where linear amplification with high output is necessary. This combination is not entirely satisfactory, however, and one of the major efforts of the laboratory is toward the development of a satisfactory indicator for individual cycles.

[2] "Fuel Injection With Spark Ignition in an Otto-Cycle Engine," by C. F. Taylor, E. S. Taylor, and G. L. Williams, *S.A.E. Journal*, March, 1931.

[3] "A New High-Speed Indicator," by E. S. Taylor and C. S. Draper, MECHANICAL ENGINEERING, March, 1933.

EXPERIMENTAL PROGRAM

In the case of this particular laboratory, it has seemed unwise to encroach on that field which is best suited to industrial research, or on that field which is best handled by experts in pure chemistry or physics. Fortunately, there is no dearth of problems within this range, and the difficulty in planning a program is chiefly one of avoiding duplication of the work of similar laboratories, and of eliminating unimportant projects. As in almost any other scientific activity, it is necessary to avoid extreme diversification. Concentration of effort on a few problems develops experience, apparatus, and technique much more effectively than the spreading of effort over too many fields.

THERMODYNAMIC PROBLEMS

Thermodynamic projects now in progress are the following:

(1) A study of the physics of the detonation process, including investigations of instantaneous pressures, frequencies of pressure variations, and similar physical phenomena. This work requires delicate instrumentation, and progress so far has been confined largely to the development of pressure-indicating elements responsive to high frequency. This work has recently met with considerable success, and it is hoped that the results can be published in the near future.

(2) A photographic study of cylinder flames. A cylinder head with a long glass window and a special high-speed camera is the principal apparatus employed. The spectrograph may be used later, if it is found that useful results, not heretofore obtained, are likely to be forthcoming. Under this heading, also, an attempt is being made to determine the velocity of flame propagation during detonation.

(3) Measurement of detonation. The laboratory holds a membership in the Detonation Subcommittee of the Cooperative Fuel Research Committee. In addition to cooperating in detonation rating, an exhaustive research into the technique of detonation measurements is now under way. It is hoped that this will result in the development of improved apparatus to measure the intensity of detonation.

COOLING RESEARCH

The laboratory program includes two projects in this field:

(1) Determination of the relative amounts of heat which are dissipated to the various parts of an engine cylinder. For

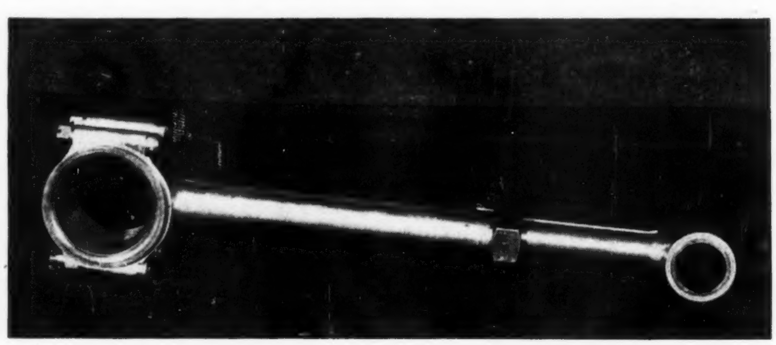


FIG. 3 ADJUSTABLE CONNECTING ROD

this purpose a cylinder has been prepared with separate water jackets covering, respectively, the cylinder barrel, the cylinder head, the intake port, and the exhaust port. The amount of heat dissipated to each of these parts is being investigated under a wide variety of operating conditions.

(2) A study of the mechanism and rates of heat transfer from various types of radiating surfaces to air moving at high velocities.[4] To date this study has covered a considerable amount of work on the heat-transfer characteristics from a smooth metal surface to an air stream flowing parallel to that surface. A start has also been made on a determination of the effect of adding to the heated surface various types of cooling fins, such as are used on air-cooled cylinders.

MIXTURE-PREPARATION STUDIES

Problems of carburetion, distribution, and fuel injection are properly classed in this field. Several such studies are now being actively pursued in the laboratory:

(1) Fuel injection with spark ignition. A program of research in this field has been under way for more than two years.[2,5] This work is to be extended to other forms of combustion-chamber and other injection-system constants. Perhaps the most significant finding in this research has been that performance superior to that with a carbureter and gasoline is possible with fuels having much lower volatility.

(2) Fuel injection with compression ignition. The main feature of the program in this field is the coordination of the available results of spray research with the actual performance of such sprays in an engine cylinder.[6] A special single-cylinder engine (Fig. 2) is now being used for this research. It is a 6 by 8 in. four-cycle unit with a single sleeve valve, mounted on one of the universal crankcases already described.

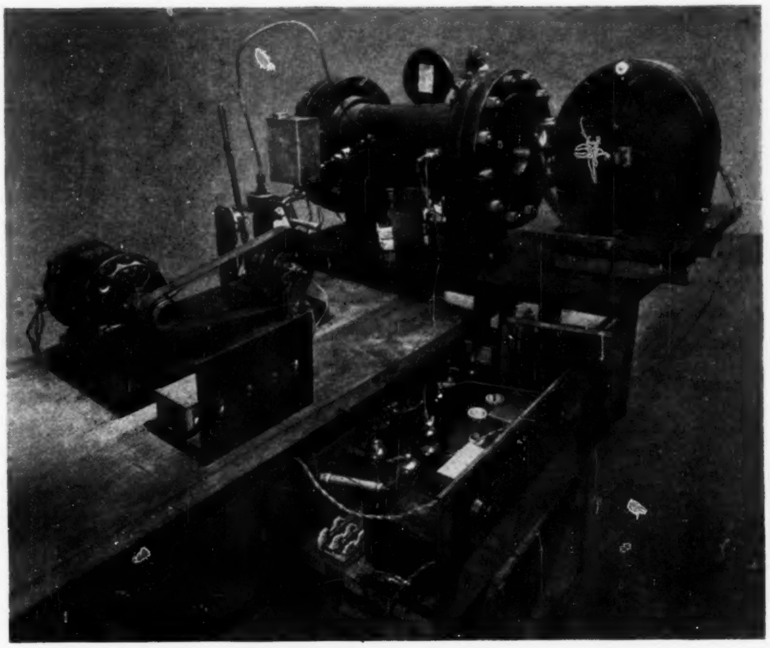


FIG. 5 EQUIPMENT FOR PHOTOGRAPHING FUEL SPRAYS

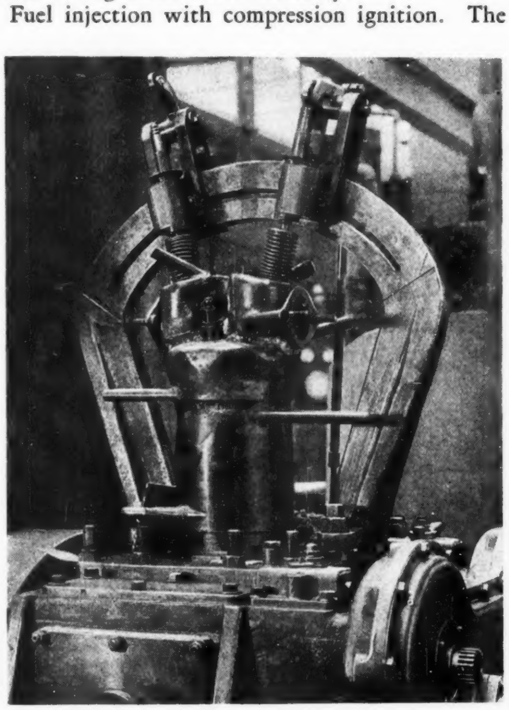


FIG. 4 ADJUSTABLE VALVE-GEAR YOKE ON UNIVERSAL CRANKCASE

In planning this program it has been realized from the outset that spray characteristics, combustion-chamber design, and turbulence are interconnected in such a way that the number of combinations involved will be very large. For the present, three combustion-chamber shapes have been selected. These are all cylindrical, with height-diameter ratios of $^1/_2$, 1, and 2, respectively. In each of these combustion chambers a series of nozzles will be used with the usual variations of the injection constants. The turbulence or swirl may be varied from a maximum of 12 times engine rpm to the point of no swirl, by means of vanes in the inlet ports. It is hoped that this series of experiments will give a useful correlation between spray characteristics and engine performance under controlled conditions. The work can be extended later to more complicated combustion-chamber forms.

(3) Another item on the Diesel research program is that of cooperation with the joint A.S.M.E. and S.A.E. committee on Diesel fuel specifications, and it is hoped that the cylinder described, together with the other compression-ignition cylinders available in the laboratory, can be used to advantage in this work.

(4) Spray photography. In order to define the spray forms to be used in the compression-ignition research, a small apparatus has been built for photographing fuel sprays under simulated cylinder conditions. A cylindrical steel bomb (Fig. 5) contains both the spray and the source of light. The latter consists of a semi-circular mercury-vapor tube which is so controlled as to emit successive flashes, each of the order of 10^{-6} seconds duration. It has already been found possible to make photographs with this apparatus at the rate of 2000 per second.

[4] "Rate of Heat Transfer From Finned Metal Surfaces," by C. F. Taylor and A. P. Rehbock, N.A.C.A. Technical Note No. 331, January, 1930.

[5] "Further Investigation of Injection in an Engine Having Spark Ignition," by E. S. Taylor and G. L. Williams, *S.A.E. Journal*, January, 1932.

[6] "Compression-Ignition Tests With a Sleeve-Value Engine," by C. F. Taylor and M. S. Huckle, *Diesel Power*, September, 1933.

MECHANICAL ENGINEERING

Vol. 55 NOVEMBER, 1933 No. 11

GEORGE A. STETSON, *Editor*

The E.C.P.D. Makes a Good Start

ENGINEERING HISTORY was made on October 10, 1933, when the Engineers' Council for Professional Development held its first annual meeting and transmitted to the governing boards of its constituent bodies recommendations based on the reports of its four standing committees. Space and time will not permit a complete account of the meeting and of the dinner which followed, although it is hoped that some of the reports may be more adequately treated in subsequent issues.

The E.C.P.D. is a joint advisory council to its seven constituent bodies, the Am. Soc. C.E., A.I.M.E., A.S.M.E. A.I.E.E., A.I.Ch.E., S.P.E.E., and N.C.S.B.E.E. (National Council of State Boards of Engineering Examiners). Its purpose is to raise the status of the engineering profession. A statement of its objectives was published in the September, 1932, issue of MECHANICAL ENGINEERING, page 633. Temporarily organized on October 3, 1932, under the chairmanship of C. F. Hirshfeld, the Council has been functioning through its executive committee and four standing committees. The reports of the standing committees provided the principal business at the Annual Meeting, and were passed on to the governing boards of the constituent societies for action. These committees and their chairmen are: Selection and Guidance of Students, R. L. Sackett; Engineering Schools, K. T. Compton; Professional Training, R. I. Rees; and Professional Recognition, C. N. Lauer.

The comprehensive nature of the Council and its program is evident from its sponsor bodies—the professional societies, representing civil, electrical, mechanical, mining, metallurgical, and chemical engineering; the licensing boards; and the engineering colleges—and from the scope of its standing-committee interests, which cover pre-collegiate, collegiate, and post-collegiate selection and recognition up to the time a man is a fully qualified member of the engineering profession, a period covering, possibly, 10 to 20 years of his life.

SELECTION AND GUIDANCE

The report of the Committee on Selection and Guidance of Students dealt with the problem of guidance only. It was reported that there was a need for guidance information. The manner of treatment of existing guidance books and pamphlets on engineering were criticized on the grounds of being too factual and insufficiently emotional. Comments of the National Occupational Conference on the problem of guidance were reported and the findings of a subcommittee which made a study of guidance literature were summarized. The committee proposes to obtain the cooperation and assistance of individuals and organizations experimenting or using occupational-guidance procedures. In receiving the report, the Council urged the committee to direct its attention also to the problem of selection.

Discussion of the report brought out the important fact that engineering schools provide an excellent training for men who do not intend to enter the more strictly technical pursuits of design and operation of engineering and industrial enterprises. As there is an increase in the number of men so educated, the problem continually confronting the engineer of making his point of view intelligible to his fellow citizens becomes easier and a sympathetic comprehension of the complications of an industrialized society more universal. Engineering schools should continue to educate men for the nontechnical fields.

ENGINEERING SCHOOLS

The Committee on Engineering Schools recommended that the E.C.P.D. "undertake a program of accrediting the several curricula of the various schools of engineering which are deserving of approval by the Council as representing sound and adequate instruction in various professional fields of engineering." It recommended that the Council approve a proposed basis for accrediting engineering colleges that should (1) apply only to curricula leading to degrees, both undergraduate and graduate, (2) be by courses of study rather than by schools, and (3) be on a qualitative as well as a quantitative basis, the qualitative data being evaluated through visits of inspection and the quantitative data from catalogs and from questionnaires, a proposed form of which was submitted. The report also proposed that seven regional committees be formed, with a paid headquarters staff, to provide an organization for accomplishing the accrediting. Means of financing were also suggested.

PROFESSIONAL TRAINING

The Committee on Professional Training has for its objective "the preparation of a program which will combine the early experience of the young graduate engineer with a plan of study and further intellectual development until he is qualified for full professional status." It reported on a survey which is being made of the junior members, or equivalent levels, of the constituent bodies of the Council. It has given much study to the preparation of a self-analysis blank whose object is to assist the individual in making a program for his own future development. The committee plans to undertake a survey of educational facilities in areas of concentration of junior membership. It has prepared a tentative reading list of 100 titles to assist junior engineers in undertaking selective and purposeful reading. It plans to prepare a bulletin to include a synopsis of experience and further intellectual development de-

manded by criteria set forth by the Committee on Professional Recognition. It also proposes to develop procedures calling for the participating in its work of member bodies, their divisions, regions, and local sections.

PROFESSIONAL RECOGNITION

The Committee on Professional Recognition is concerned with standards for entrance to the profession and the methods of establishing and maintaining them. A statement of policy in its report stated that recognition should be earned; that educational qualifications should be more advanced than graduation from college, yet attainable by non-college men; that attainments should be tested individually by examination, written and oral; that educational qualifications should comprise scientific, technical, economic, and civic knowledge of a mature order; that colleges should be urged to grant the professional degree to those who have been certified; that state registration boards also should recognize certification as an essential requisite for the registration of an engineer; and that the certification should be prima facie evidence of technical proficiency for admission into the corporate membership of the societies.

Minimum qualifications for an engineer set up by the committee are:

"(*a*) Graduation from an approved course in engineering of four years or more in an approved school or college; a specific record of an additional four years or more of active practise in engineering work of a character satisfactory to the examining body (the examining body, in its discretion, may give credit for graduate study in counting years of active practise); and the successful passing of a written and oral examination covering technical, economic, and cultural subjects and designed to establish the applicant's ability to be placed in responsible charge of engineering work and to render him a valuable member of society; or alternatively.

"(*b*) Eight years or more of active practise in engineering work of a character satisfactory to the examining body and the passing of written and oral examinations designed to show knowledge and skill approximating that attained through graduation from an approved engineering course and also examinations, written and oral, covering technical, economic, and cultural subjects designed to establish the applicant's ability to be placed in responsible charge of engineering work and to render him a valuable member of society."

Uniformity of grades of membership in the various societies was also recommended by the committee. These grades are "student member," "junior member," and "member." The "member" is to be a full-fledged engineer who has satisfied the alternative requirements in the minimum definition of an engineer. The committee then urged that the minimum requirements for membership, the license, and the professional degree be in substantial agreement with the minimum definition. It recommended (1) the adoption of its policy, (2) approval of the minimum definition of the engineer and its adoption by the participating bodies, (3) approval and adoption of its proposed grades of membership, and (4) consideration by engineering schools of the bestowal of professional degrees on none but those who have attained the minimum standard.

THE SIGNIFICANCE

The foregoing brief and inadequate review of the reports of the first year's activities is an indication of the practicability of cooperation in an endeavor of major importance to the engineering profession by organized groups having different points of view. First steps have been taken harmoniously. The broad and comprehensive scope of the program being undertaken appeals strongly to the hopes and ambitions of all engineers who respect their profession and wish to see its status raised, its prestige enhanced, and the quality of its membership improved. The economy of procedure by which it is hoped to make possible, simultaneously and by a single agency, professional, legal, and academic recognition of individual attainment, with the consequent unification of practises in the societies, the state licensing boards, and the engineering colleges, will appeal strongly to practical men, both inside and outside the profession. The substitution of earned recognition on the basis of education and actual attainment, as tested by examination, for certification by testimonial gives distinction to those who acquire the right to be called engineers under the proposed definition and will do much to elevate the professional status in the eyes of the law and the public. The bold proposal to accredit curricula in engineering will be heartily applauded by the real friends of engineering education, as honest and competent accrediting will most certainly improve the quality of instruction and the quality of graduates from engineering schools.

THE IMMEDIATE FUTURE

But the filing of four reports of progress and recommendations for constructive and intelligent cooperative action designed to improve the status of the engineering profession will not, of itself, accomplish what the Council has set out to do. Much more is needed. Hopes and suggested procedures will mean nothing without purposeful action on the part of the constituent bodies. The engineering societies must set their houses in order; the schools must be convinced of the necessity of cooperating in the movement to elevate the status of the profession, and the licensing agencies of the various states must be made to see the desirability of the procedures proposed. Harmony of action, such as has prevailed so far, must be fostered. The least that the individual engineer can do is to accord the program of the Council his sympathetic interest so that when the time comes for the discussion of proposals and for necessary actions to expedite it, his opinions will be constructive and intelligent. The engineering profession is facing one of the greatest tasks it has ever jointly undertaken. Let every individual lend his support.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Simplified Aerodynamic Analysis of the Cyclogiro Rotating Wing System

THE cyclogiro is a power-driven rotor in which the blades describe a cycloidal path. (In this connection see "Cycloidal Propulsion Applied to Aircraft," by Prof. F. K. Kirsten, presented at the National Aeronautical Meeting, Buffalo, N. Y., June 28 to 29, 1928, and published in Transactions, A.S.M.E. (1927–1928), paper AER-50-12.)

It is said that this rotor possesses promise in the field of hovering flight and vertical ascent, in addition to a reasonable speed in level flight. A simplified aerodynamic theory of the cyclogiro is here presented. The rotor consists of several blades rotating about a "horizontal axis perpendicular to the direction of normal flight." The angle of the individual blades to the tangent of the circle of the blade's path is varied by a double-cam arrangement so designed that the period of oscillation of the blades about their span axis may be changed both in amplitude and in phase angle. The net force on the rotor may thus be varied in magnitude and direction by movements of the cams.

It is stated that on the basis of certain assumptions, the equations developed for the net force and torque of the cyclogiro rotor give satisfactory qualitative relations between the rotor characteristics and the parameters affecting them. It can then be stated that the aerodynamic principles of the cyclogiro are sound. The control system will be necessarily complicated mechanically and gyroscopic couples in the rotor will add complexities.

It is recommended that theoretical study of the system be supplemented by experiment.

Among the conclusions it is noted that hovering flight, vertical ascent, and reasonable forward speed are obtained without excessive expenditure of power and the cyclogiro rotor will autorotate in a gliding descent. (John R. Wheatley, National Advisory Committee for Aeronautics, Technical Note No. 467, August, 1933, 13 pp. of text and 16 figs. on plates, *tm*)

Strandgren Rotors

THE strandgren rotor consists of a certain number of equidistantly distributed wings about a horizontal axis of rotation and parallel to that axis. Each wing is so held that it can oscillate about an axis parallel to its span at the same time that it turns about a general axis of rotation. A system of controls is provided to make it possible to vary the manner of oscillation of the wings in a way to produce the desired effect, such as sustentation at a fixed point, simultaneous sustentation and propulsion, descent in volplane, vertical descent in autorotation, etc. Moreover, by operating the two rotors differentially, all kinds of evolutions of the apparatus about its center of gravity may be obtained. The Strandgren machine has no supporting planes, no propeller, and no steering organs other than the two rotors. It is said that it can fly in any direction—vertically, horizontally, backward and forward—at any speed between zero and maximum. Like an airplane, it has a most economical speed determined by a certain ratio between the velocity of translation and the velocity of rotation of the wings, but it can fly at any other speed and may stop in the air. The apparatus is being developed by the National Inventions Bureau of the French Government and the Franco-Scandinavian Expansion Company. It is not described in any detail in the present article which gives, however, a mathematical theory of its action not suitable for abstracting. (C. B. Strandgren in *L'Aérophile*, vol. 41, no. 7, July, 1933, pp. 209–215, illustrated *mA*)

Engines

THE following is quoted from the report for the year 1932–1933 of the Aeronautical Research Committee.

It was pointed out in last year's report that the production of still lighter petrol engines now depended mainly in improvements in detail, but that much remained to be done in promoting fuel economy, especially under cruising conditions. Following the development at the R.A.E. of a device for the automatic control of fuel-air mixtures, recent investigations have provided results of outstanding interest. It has been shown that it is possible to reduce fuel consumption at the reduced power required for cruising to a figure very substantially below anything attained in flight hitherto. This work is being actively pursued with a view to the reproduction in flight of results obtained on the test bed. Successful development along these lines should be of considerable interest to civil air transport.

Research on heavily supercharged single-cylinder units has been continued. In the case of petrol engines, it has been shown that the indicated power increases practically proportionally to the degree of supercharge up to initial pressures as high as three times the normal pressure. It has been found, however, that whereas at ordinary pressures it is possible to get satisfactory combustion of weak mixtures of petrol and air, the effect of supercharging is to narrow the practical range of mixture strength. Apart, therefore, from the loss of economy to be expected in a superheated engine by reason of the necessary lowering of compression ratio, and from having to drive its own superheater, it appears that definite limitations to the degree of supercharging in practise may be imposed by difficulties of combustion rather than by mechanical considerations.

When compression-ignition engines are supercharged, the indicated power does not increase in proportion with the initial pressure. Theoretical investigations indicate that this difficulty is not likely to be overcome by improvements in design, and therefore that the production of light compression-ignition engines will not be facilitated by heavy supercharging. A moderate degree of supercharging has, however, many advantages. As stated in last year's report, it is considered that the development of the two-stroke compression-ignition engine holds out the greatest promise of success in the production of a satisfactory power unit sufficiently light to compete with the petrol engine.

At present, research is proceeding at the works of Messrs. Ricardo and Co. upon a sleeve-valve unit, and it is advised

that there is a likelihood of the construction in this country of an alternative type of two-stroke engine in which two pistons are employed per cylinder. At the same time, development is proceeding normally on various types of four-stroke engines, and with these valuable practical experience is being accumulated. (*The Engineer*, vol. 156, no. 4051, Sept. 1, 1933, pp. 214–216, *ge*)

APPLIED MECHANICS

The Behavior of Fluids in Turbulent Motion

MATHEMATICAL methods have so far failed to reveal actual internal motions of eddying fluids and we are compelled to resort to direct observation and measurement. The author deals practically exclusively with completely developed turbulence only. The investigation is a very extensive one and cannot be abstracted in detail. The author considers first the conditions at the boundary of a fluid in eddying motion, such as the flow near a solid wall, and asks what do we know of the mechanism by which the resistance to flow is transmitted to the wall. In this connection he considers the gradient of mean velocity and refers particularly to experiments of Whetham. The experimental methods involving the use of an ultramicroscope are described.

The author concludes that when the general motion is eddying, the conditions of flow very near the surface are not the same as those which exist in a streamline flow which gives the same friction on the surface.

The author discusses next such theories of eddying motion as Prandtl's *Mischungsweg* in its original German form and the new conception introduced by von Kármán and Taylor. He compares these theories and comes to the conclusion that while the two solutions (Taylor's and Prandtl's) for the distribution of the mean velocity in the wake behind the circular rod are the same, actually, it is not quite so. He also states in another connection that for a *given* velocity distribution, the temperature distribution in the wake of a heated obstacle is determined by a thermal conductivity, which, according to the vorticity-transport theory, is twice as great as the value required in the momentum-transport theory.

In the equation of heat transport there is also considerable disagreement between the Prandtl and Taylor theories. To discriminate between the two theories, Professor Taylor suggested to the Aeronautical Research Committee that experiments should be made to measure the distribution of temperature and velocity in the wake of the heated obstacle. These experiments have been made by Falkner and the author with certain obstacles, and the measurements are plotted in Fig. 11 in the original article. A conclusion drawn from this evidence is that the momentum-transport theory does not hold for the type of flow selected.

The failure to account for the observed results no doubt arises from the neglect of the theory to take account of the effect of the local variations of pressure. In fact, theoretical arguments are advanced by Professor Taylor to show that agreement between the two theories would only be expected when the turbulent motion is two-dimensional and the disturbances are confined to planes normal to the direction of the mean motion.

On the other hand, support is given to Taylor's theory by the fairly close agreements obtained between the predicted distributions of temperature and velocity and those obtained by direct measurement. There is, however, good reason to believe that one of the conditions assumed in the theoretical predictions, namely, that the disturbances are confined to planes normal to the length of the obstacle, was not realized in the experiments. Nevertheless, the evidence given in Fig. 11 in the original article does not suggest that the vorticity-transport theory represents the facts much more closely than the momentum-transport theory.

The matter of disturbed velocities in the wake of a body is considered next. Some of the experiments led the author to believe that in general the disturbances in the eddying wake behind long bluff obstacles will be three-dimensional, and the disturbances in the eddying wake behind any long body, bluff or streamline, placed with its length normal to the stream, will be three-dimensional if the Reynolds number is sufficiently high, even though the mean flow in planes at right angles to the length tends to be two-dimensional.

Among other things noted in the paper are the following: The turbulent motion close to the surface is in the main transverse to the direction of mean motion; and there is a remarkable tendency for the three components of turbulent motion toward equality. (A. Fage, paper before The Royal Aeronautical Society, Dec. 1, 1932, abstracted through the *Journal* of The Royal Aeronautical Society, vol. 37, no. 271, July, 1933, original paper pp. 573–593, 12 figs., and discussion pp. 593–600, *eA*. Particular attention is called to the discussion by Prof. L. Prandtl, pp. 597–598)

CORROSION (See Lubrication: Corrosion Effects of Lubricants Upon Bearing Surfaces)

FOUNDRY

Vertical Centrifugal Casting of Non-Ferrous Alloys

THE present article deals primarily with the production of centrifugally cast phosphor-bronze gear blanks. It has been found that the most suitable speed at which the mold should rotate is one which gives about 60 to 70 lb per sq in. pressure on the metal face of the mold. It is doubtful whether the centrifugal casting of blanks under 7 in. is worth the trouble, as very great peripheral speeds would be necessary to obtain the desired pressure. A further precaution which is vitally essential if good work is to result is to insure that none of the metal solidifies before the mold is full and rotating at the maximum calculated speed. Failure to do this results in the formation of layers in the metal separated in the case of high-tin alloys by a thin film of the eutectic alloy.

The most remarkable effect of centrifugally casting bronze is the enormous decrease in grain size obtained compared with that of chilled or sand-cast metal of the same analysis. (R. C. Stockton, *The Metal Industry*, vol. 43, no. 5, Aug. 4, 1933, pp. 97–98, 5 figs., *d*)

FUELS AND FIRING (See also Power-Plant Engineering: Removal of Solid Sulphur Compounds From Combustion Gases)

Oil-Coal Fuel

A SECTION of the recent World Petroleum Congress was devoted to oil-coal fuels, meaning thereby the fuel of finely divided coal suspended in and burned with oil. This article is based on a summary of the proceedings prepared by Dr. R. Lessing, the general reporter for this section. Coals of minimum ash content will have to be selected for this pur pose wherever fly ash is objectionable.

A. B. Manning described the work carried out at the British Fuel Research Station on the stability of suspensions of coal in oil. He found that petroleum oils, such as paraffin oil and raw fuel oil, whose viscosity, as is well known, does not increase sufficiently with decreasing rate of shear to confer the required stability on coal suspensions therein, can be made to support pulverized coal (85 per cent through 200-mesh I.M.M. screen) by previously dispersing 0.1 to 0.5 per cent of sodium stearate in the oil. The viscosity of the oil under normal conditions of flow is thereby increased, but not unduly. The viscosity at small rates of shear, however, increases rapidly as the rate of shear diminishes, and indeed becomes infinite under the shearing forces involved in supporting small particles of coal. In other words, toward such particles of coal, the dilute gel behaves as an elastic solid and will support them indefinitely. It is not essential that the oil should have a gel structure in order to confer on the coal-in-oil suspension the relative stability requisite for practical purposes (e.g., no appreciable settling in six months). This degree of stability may be given by any treatment which affects the viscous properties of the oil in such a manner that its viscosity under low rates of shear has a sufficiently high value, while its viscosity at the rates of shear involved in normal flow remains low enough to give suspensions which can be readily pumped, etc. He concludes that the variation of the viscosity of an oil at low rates of shear is the determining factor from the point of view of the stability of suspensions of pulverized coal therein.

G. Benthin regards brown coal as particularly suitable for preparing oil-coal fuels, as its composition insures greater stability of the mixture. He considers that the ash content of the oil could be reduced by centrifuging the mixture, assuming that it were possible to peptize the coal residuum, that is, the portion insoluble in organic solvents and sodium hydroxide.

W. Schultes told about tests carried out on a boiler. The boiler, which had been heated up by gas prior to firing the oil-coal mixture, had attained normal running conditions. The fuel gave a steaming efficiency of 81.5 per cent. The mixture was sufficiently fluid to be pumped and led from pressure vessels to the burners. No sedimentation of coal was observed during the two tests, which, however, were of only six hours' duration. The tests are interesting in that only coal and a coal-product oil were employed in the preparation of the fuel used. (*The Steam Engineer*, vol. 2, no. 12, September, 1933, pp. 513–515, *g*)

Sulphur Recovery From Flue Gases as an Economic Process

THE process in operation is described, but the location of the plant is not stated. The hot flue gases are scrubbed with milk of lime. The process is managed so that the sediment deposits itself, leaving a clear effluent to all intents and purposes free from oxygen-absorbing properties and therefore in a position to be discharged into rivers and drainage. It is claimed that the whole operation is under complete control as far as the quality of the precipitate and effluent is concerned. The details of the plant, which is manufactured by the Chemical Engineering and Milton Patent Furance Co., Ltd., are given in the original article. The ultimate object aimed at is to utilize the sulphur in the sludge and recover lime for use again. It is stated that roughly $1^1/_2$ tons of lime are required for each ton of sulphur contained in the coal and 200 to 300 gal of water are required per ton of coal burned when containing about 2 per cent of sulphur. (*Steam Engineer*, vol. 2, no. 12, September, 1933, pp. 534–536, 2 figs., *d*)

HYDRAULICS (See also Internal-Combustion Engineering: Hydraulics of High-Speed Fuel Injection)

Draft Tubes for Modern Hydraulic Turbines

A DISCUSSION of the reasons for the increased use of the elbow-type of draft tubes in hydroelectric power plants. The author discusses briefly the Thurlow backwater suppresser and the Moody ejector turbine and refers, again briefly, to the influence of draft head on runner cavitation and pitting of hydraulic-turbine runners. This part of the discussion is based on the data collected by the Hydraulic Power Committee of the National Electric Light Association (Report, 1924). The author gives a formula for the barometric head involving σ which is the "coefficient of total pressure drop" or the "coefficient of the blade pressure." This formula is intended as a guide until something more satisfactory is produced. (J. S. Ball, who was awarded the *Canadian Engineer* Prize for his thesis on draft tubes for modern hydraulic turbines, this prize being awarded by the University of Toronto, annually, for the best thesis on a subject pertaining to highway construction, hydraulic works, etc. Abstracted through *The Canadian Engineer*, vol. 65, no. 5, Aug. 1, 1933, pp. 5–7, this being the third and last instalment of an abstract of the original thesis. The two previous instalments appeared in *The Canadian Engineer*, June 6 and July 4, 1933, *dt*)

INTERNAL-COMBUSTION ENGINEERING (See also Railroad Engineering: Diesel-Electric Locomotives for Russia; Diesel Railcars)

The Blackstone "Fuelol" 5–7 Bhp Diesel Engine

THIS engine was exhibited at the recent Royal Show. Its special feature is a patented system of injection. The fuel pump is fitted on the side of the engine and delivers oil under pressure to the sprayer in the cylinder head in metered quantities which are varied by the governor according to the load on the engine. The operation of the pump is said to be such as to insure a sharp opening and closing of the sprayer valves and eliminate dribble. The action of the equipment is described in detail in the original article which shows diagrammatically the action of the fuel-injection system. It is said that in the small engine the fuel consumption works out at approximately 0.44 lb per bhp-hr. (*Mechanical World*, vol. 94, no. 2432, Aug. 11, 1933, p. 761, 2 figs., *d*)

Friction Losses

FRICTION losses in engines were analyzed by L. C. Lichty and G. B. Carson, of Yale University, and the results are given in the form of curves. It is claimed that the pump and other losses, except piston and ring friction, are not affected by the jacket temperature, while piston and ring friction decrease materially with an increase in jacket temperature.

At jacket temperature of 60 F the friction with all the rings removed was practically the same as with all the rings in place. When the oil ring was removed, the friction was greater than when it was in place, and this is ascribed to the uncontrolled film of oil all around the piston, which greatly increases the shearing effect.

At the low jacket temperature, the friction loss due to the reciprocating parts is 7.9 hp at rated speed, and at the high jacket temperature, 180 F, it drops to 4 hp, a decrease of 49.3 per cent. This, the authors point out, is a definite indication that cylinder-block temperature controls the temperature of

the oil film on the cylinder wall, and that the shearing of the oil film by the reciprocating parts in all probability makes up the major portion of the friction losses due to the reciprocating parts when operating at low engine temperatures. The loss due to the reciprocating parts is about 59.8 per cent of the total mechanical friction loss at the low jacket temperature, and about 43.5 per cent of the entire frictional loss of the engine. At the high jacket temperature these ratios are 43.5 per cent and 28.6 per cent, respectively.

The conclusions drawn from the analysis are that the friction of the reciprocating parts has a preponderating effect in determining the overall efficiency of the engine and that the compression rings are responsible for most of the friction of the piston and ring assembly. (Paper before the Automotive Engineering Congress, Chicago, Aug. 28 to Sept. 4, 1933, abstracted through *Automotive Industries*, vol. 69, no. 9, Aug. 26, 1933, p. 236, 1 fig., *e*)

Hydraulics of High-Speed Fuel Injection

THE author has undertaken to summarize the extent of current knowledge of the subject and indicates that while the present state of the art does not permit the setting up of formal rules for predicting the exact behavior of the fuel injection mechanism as a hydraulic system, enough is known to indicate the qualitative behavior. He lists the elements affecting the flow through the system as well as those which determine the rate of injection. He points out that the building up of pressure in the fuel pump, the piping, and the fuel injector is always a dynamic process and analyzes it in detail. This analysis includes the pressure wave in and at the injector. He considers in detail the subject of the injection lag, which is the time elapsed from the creation of the first pressure wave in the pump to the beginning of injection at the nozzle. He does not believe that the injection lag is caused either by the compressibility of fuel contained in the piping or the elasticity of its material. He claims that injection lag is independent of the volume of fuel contained in the piping and is affected only by the pressure which remains in the fuel pipes after the conclusion of the injection (line pressure) and by the length of piping. He claims that the elasticity of the pipes now commonly used for fuel-injection lines on high-speed Diesel engines has no effect at all on injection lag.

Attention is drawn to the difference between injection lag and ignition lag, which is very often disregarded in practical engine operation. With engines for automotive purposes, the compression end pressure varies with the engine speed, being the lowest for slow speed, and the highest at maximum speed. Since ignition lag varies inversely as to the compression pressure, much more can be achieved by increasing the compression pressure to avoid the use of variable timing on the engine, than by shortening the fuel pipes. (Nicholas Fodor, Automotive Engineering Congress, Chicago, Aug. 28 to Sept. 4, 1933, abstracted through *Automotive Industries*, vol. 69, no. 9, Aug. 26, 1933, pp. 248–249, *t*)

Lanova Air-Cell Diesel Engine

THE Lanova engine has been described in MECHANICAL ENGINEERING (vol. 54, no. 4, April, 1932, p. 287), and it is now said that extensive tests have recently been carried out by Prof. A. Loschge with a new type of Lanova engine. These tests were carried out with a four-cylinder four-stroke-cycle engine of 4.72-in. bore and 7.08-in. stroke and having a normal working speed of 1000 rpm. The mean effective pressure of this engine could be raised to $111^1/_2$ lb per sq in. with the exhaust remaining perfectly clear; at maximum load the excess-air figure was 1.13, so that the available air volume must have been almost fully utilized. The volumetric efficiency was established at 84 per cent at 1000 rpm, which is a distinctly high value at this speed. At 1000 rpm and running under all load conditions between 27 and 70 bhp, the highest specific fuel consumption was found to be 0.447 lb per bhp-hr; the minimum consumption recorded was 0.410 lb per bhp-hr with a load of 45 bhp. The engine speed being raised to 1400 rpm, corresponding to an output of 94.2 bhp; the fuel consumption was only 0.415 lb per bhp-hr. The maximum mean effective pressure was constant at 111 lb per sq in. at all speeds between 600 and 1000 rpm, while at 1200 rpm it dropped slightly to $109^1/_2$ lb per sq in. and at 1400 rpm to 106.7 lb per sq in. The final compression pressure was 341 lb per sq in. and the maximum working pressure, as recorded by the indicator, was 597 to 625 lb per sq in. With an atmospheric temperature of 23 F and the doors of the engine house wide open, the cold engine started working after eight revolutions and immediately idled with a speed of only 160 rpm.

These figures are stated to be characteristic of engines fitted with Lanova air cells. In Germany, Henschel & Sohn, of Kassel, have acquired a manufacturing license and are now turning out six-cylinder engines of 4.33-in. bore and 6.3-in. stroke and delivering 110 bhp at 1500 rpm. The normal output is 95 bhp at 1250 rpm; the mean effective pressure is given as 106 lb per sq in; and the fuel consumption as 0.407 lb per bhp-hr. This engine weighs, complete, 1994 lb, or 18.1 lb per bhp on the maximum rating. (Edwin P. A. Heinzl, *Diesel Railway Traction*, supplement to *The Railway Gazette*, June 16, 1933, pp. 17–18, 3 figs., *de*)

High-Speed Oil-Engine Design

IN POWER output per unit of piston-swept volume, the oil engine is now the equal of the gasoline unit, which is, however, so only among the highly rated engines. The unit weight of the lightest designs is no greater than that of a normal gasoline engine and in transport work this may be turned to a gain by the lesser weight of fuel required for a given distance. The lightest weight per unit of volume is not found in the highly rated engines, but in those with a relatively high cylinder capacity developing a low brake-horsepower per unit of volume. In these cases, the power is developed at what is now considered the low speed, viz., under 1500 rpm.

The provision of an air storage cell has the additional advantage of enabling the injection pressure to be lowered to a value corresponding to that of an ante-chamber combustion engine. It would appear that the latter type of construction will be ousted by other forms, which have the same advantages plus a higher thermal efficiency and a somewhat lower compression ratio. Compression ratios have increased a little within recent years, although direct-injection designs do not reach 15 to 1. Ratios of ante-chamber combustion engines are, of course, in the main consistently higher than those of the air-storage or the direct-injection engine. The maximum combustion pressure appears to bear no fixed relation to the compression pressure, even with similar types of head and the same compression ratio, but it is worth remarking that the compression ratio, of itself, forms no guide to the working pressure attained in service. The absolute pressure at the commencement of the compression stroke must be accurately gaged, but, even so, indicator cards show that the usual exponent of 1.35 in the *P-V* expression for actual engines requires some modification. The Deutz approximates to the constant-pressure cycle, the remainder all having a considerable amount

of that explosive effect which is a characteristic of the constant-volume principle.

Injection pressures above 2000 lb per sq in. are a thing of the past, except for the two-stroke opposed-piston Junkers engine, which has a minimum designed pressure of 3000 lb per sq in. The opposite extreme is reached in the Büssing-N.A.G. engines, in which an injection pressure of only 955 lb per sq in. is used in conjunction with a compression ratio of 17.5 to 1, and a maximum gas pressure of 810 lb per sq in.

A summary of the main constructional features of a selection of engines is given in a table (Table III) in the original article. The practise of building up engines in two or three cylinder blocks is losing ground. Where the unit method is employed the crankcase is never integral with the cylinder blocks but monoblock cylinders may be separate from the crankcase or cast integrally with it.

In the latest four-cylinder Daimler-Benz engine liners are omitted, though the cylinder and crankcase are formed in one casting. In one type of engine one inlet and one exhaust valve are universal. Contrary to what might be expected, the average diameter of the valves has decreased with the increase in rotational and piston speeds. The average valve-diameter–cylinder-bore ratio of a dozen engines in existence three years ago was 0.424, while the mean of the examples included in a table of modern engines in the original article is 0.402. The various injection systems and cylinder-head types do not appear to exert any influence in the choice of the valve diameter, except that a precombustion chamber limits the size.

It is in material that the valves have made the greatest advance, simple nickel steels having given way to corrosion-resisting silicon-chrome steels, and to nickel-chrome brands possessing great toughness and high impact values. Both types are capable of giving satisfactory service at the highest temperatures met with in operation, viz., some 1600 F, but for the strenuous duties, nickel-chrome steel is used, on account of the high tensile strength at elevated temperatures which it possesses, some brands giving 16 to 17.5 tons per sq in. ultimate strength at 1450 F in conjunction with an elongation of 35 to 40 per cent.

It is in material also that pistons have made most progress, cast-iron pistons being an exception in recent designs. The length-diameter ratio of oil-engine pistons is appreciably greater than is found in gasoline engines, details of design being given in the original article.

In crankshafts, reduction of the dynamic load on the main bearings by prolonging the crank webs as balance weights does not appear to the author to have been given the attention which it deserves. While it might be expected also that the crankpins would be hollow bored to a greater degree than the shafts in order to reduce the centrifugal force, this is not the case in actual practise, the average for both being about 0.5 of the outside diameter.

In recent designs, the connecting-rod-crank ratio averages 4.1 to 1, but the shortest rods are not found in conjunction with the longest pistons, even with similar bores and piston speeds. Recent practise has firmly established the practicability of a thin white-metal lining, run directly on to the steel of the connecting rod or crankcase, for the big end and main bearings, in preference to employing a phosphor-bronze backing. The last-named material is, however, still used for the small-end bush. The necessity for adequate bearing area for the gudgeon pin in the piston bosses limits the length of the small end bearing to a maximum of approximately 0.5 of the cylinder bore, the average value being about 0.4. (R. Paterson, *The Engineer*, vol. 156, no. 4048, August 11, 1933, pp. 134–136, 4 figs., *cdA*)

LUBRICATION (See also Testing and Measurement: Measuring Oil Consumption)

The Selection of Viscosity of Crankcase Oils

THIS article is based on a joint meeting of the American Society for Testing Materials and the Society of Automotive Engineers recently held in New York City. E. W. Upham, chief metallurgist, Chrysler Corporation, reported tests on truck engines which showed that the greatest power was produced with an oil at a viscosity of less than 40 sec at the cylinder temperature and 60 sec at the crankcase temperature. No indication was found that lubrication with this oil was not entirely satisfactory, although the engine did not run as quietly as with oils of higher viscosity.

W. A. Gruse, senior fellow, Mellon Institute of Industrial Research in Pittsburgh, stated that his study suggested the desirability of hastening the day when the average motor car can use, with tolerably low oil consumption, oils of much lower viscosity than the present S.A.E. Nos. 40 and 50. He believes that the adoption of such less viscous lubricants is probably the simplest means of reducing the formation of carbon.

M. A. Dietrich, graduate student, Department of Chemistry, Ohio State University, discussed the changes which took place in oil after a certain period of operation in an engine. It would appear that when dilution and contamination are removed, the oil changes gave a slight decrease in the flash and fire points, a marked increase in viscosity and carbon residue, a minor change in specific gravity. The increase in viscosity becomes greater as volatility increases, especially in oils blended of two or more kinds differing widely in viscosity. The percentage of iron oxide in crankcase oil is related to the viscosity in a very striking manner.

According to W. H. Graves, chief metallurgist, Packard Motor Car Co., tests showed a wide difference in consumption of two oils of the same viscosity at 210 F but of different volatility. If, however, the oils are sufficiently non-volatile for the service, differences in volatility do not affect oil consumption. (*Commercial Car Journal*, vol. 15, May, 1933, pp. 21–22, illustrated, *p*)

Corrosion Effects of Lubricants Upon Bearing Surfaces

THE corrosion effect of a lubricant upon the bearing surface in actual service can be of an exceedingly complex nature. In the investigation reported here only the purely chemical effect is taken into consideration. The author states that certain additions to oil having a very slight corrosive effect upon the bearing surface may be not only not injurious but distinctly beneficial. If this corrosion tends to affect only the softest crystal in the bearing surface and the corrosive action at this point is either limited or inhibited by such corroded surface, then the slight microscopical depressions between the hard bearing crystal are increased by this chemical action, the aggregate amount of lubricant in the film is correspondingly increased, and, in consequence, an improved bearing condition results.

The pure fatty acids are all more or less corrosive with respect to the ordinary metals. Small percentages of fractionated asphaltum have been used in lubricating oils with very beneficial effects. No lubricant, however, should carry more than a trace of sulphur, copper being particularly susceptible to the corroding action of sulphur. On the other hand, a trace of sulphur just sufficient to corrode the softest crystal and not sufficient to produce general corrosion or pitting can be beneficial.

Of the fatty acids, oleic has the virtue in dilute form of not corroding the hard bearing crystals in either the copper-tin-bronze or tin-base or lead-base babbits. In amounts of a fraction of one per cent in mineral lubricating oils, it appears to increase the capillary affinity for the metal surface and produce a slight etching effect upon the softer crystal of the ordinary bearing alloy. Oxidation of mineral oil in service without other additions has several beneficial effects. (Christopher H. Bierbaum, Vice-President, Lumen Bearing Co., Buffalo, N. Y., in *The Iron Age*, vol. 132, no. 9, Aug. 31, 1933, pp. 20–21, and 58, 4 figs., *e*)

MACHINE PARTS

High-Strength Rivets

IN CONNECTION with the erection of mobile mooring masts for the United States Navy at Lakehurst, N. J., and Sunnyvale, Cal., special tests were made on rivets. These rivets had to be countersunk and have their heads finished flush. A steel of 0.30 per cent carbon and 1.60 per cent manganese was first tried, but the excessive hardness of driven rivets made from this steel presented a serious difficulty. As stated, the rivets had to be finished with their heads flush with the surface of the part. When an effort was made to remove these heads with pneumatic chisels, the chisels made from half a dozen steels failed to hold a cutting edge in chipping. The company which was doing the job then successfully tried a chromium-manganese-silicon steel known as Cromansil which not only met the requirements of the Navy Department but far exceeded them. The material was found to be free from the detrimental quality of excessive hardness after driving. What is more, it had a tensile strength of 77,000 lb per sq in. in the rolled bar turned to 0.505 in. diameter, but more than 135,000 lb per sq in. for the rivet. This would indicate a beneficial effect of the heat treatment upon the physical properties of Cromansil steel rivets. This treatment consists in heating the rivet to the necessary riveting temperature and cooling it rather quickly by contact with the cold piece. Working of the steel in the upsetting operation of riveting also imparts a beneficial effect.

To determine the physical effect of the rapid cooling of the rivet in contact with the test bar, a tension test piece was turned to 0.505 in. diameter and the ends were threaded. This test piece was heated in an electric rivet heater the same as the rivets were heated and then was clamped in a two-part chill, fitting closely to the 0.505-in. diameter. After cooling, the piece was pulled and gave the following results:

Elastic limit, lb per sq in.	81,500
Tensile strength, lb per sq in.	113,750
Reduction of area, per cent	47.0
Elongation in 2 in.	Broke outside 2-in. marks

(A. E. Gibson, Vice-President, Wellman Engineering Co., in *Steel*, vol. 93, no. 14, Oct. 2, 1933, pp. 27–29 and 37, 5 figs., *ep*)

METALLURGY

The Influence of Beryllium on Steel

THE investigation here described was carried out jointly by the research departments of the English Steel Corporation, Thos. Firth, and John Brown, Ltd., at the request of the British Air Ministry, with the object of determining whether the addition of beryllium to selected specific types of steel largely used in aircraft and aircraft-engine construction was likely to offer any direct benefit by improving the physical characteristics of the material, especially as regards the mechanical properties and resistance to corrosion. The investigation does not purport to constitute an exhaustive study of the subject.

Difficulty was encountered in introducing the effective percentage of this very light element into molten steel. The tests were made with carbon steel, 13-per cent chromium steel, 18-per cent chromium and 8-per cent nickel Austenitic stainless steel, 3.6-per cent nickel steel, and 3.5-per cent nickel and 0.80-per cent chromium steel.

The results disclosed by this investigation indicate little or no prospect that the element beryllium will become a useful addition to the group of metals used in the manufacture of special steels. The metal is extremely expensive and is unlikely ever to become reasonably cheap, while its lightness and readiness to oxidize make the actual introduction of beryllium into molten steel somewhat difficult and distinctly wasteful, even with the special method of addition employed in the present case.

As regards forging, the addition of 1 per cent of beryllium tended to make some of the steels, particularly the $3^1/_2$-per cent nickel and the nickel-chromium steels, distinctly "stiffer" under the hammer, with an increased tendency to "burst," especially toward the top end, but it is probable that this would give rise to no serious manufacturing difficulty if the beryllium steels were required for use in engineering construction because of their desirable physical properties.

In this respect, however, the addition of beryllium has proved harmful rather than otherwise.

Apart from the hardness peak in the tempering range 400 to 450 C and the associated brittleness and the liability to crack with rapid cooling, probably due to some pronounced volume change, the beryllium-bearing steels show throughout a marked liability to fragility, as evidenced by the impact test, which far outweighs the increase in tensile strength. In short, none of the steels containing beryllium has shown, with any treatment, the combination of high elastic limit and fatigue resistance with ductility and toughness which is necessary in highly stressed engine parts. It was thought that the addition of beryllium might confer upon stainless steels of the 18-per cent chromium, 8-per cent nickel type, which are normally austenitic, an increased resistance to corrosion, but in this case also the results were definitely disadvantageous. (J. H. S. Dickenson and W. H. Hatfield, paper before the Iron and Steel Institute, September, 1933, abstracted from advance copy, 23 pp., 7 figs., *eA*. Compare in this connection MECHANICAL ENGINEERING, vol. 54, 1932, pp. 520–521)

MOTOR-CAR ENGINEERING (See Lubrication: The Selection of Viscosity of Crankcase Oils)

MUNITIONS

Liquid-Air Gun

IT IS REPORTED that the first machine-gun firing with liquid air has been taken over by the German Navy. The firing speed is the same as with an ordinary machine-gun, but the liquid-air gun firing bullets of 7.5 mm diameter can shoot a distance of $5^1/_2$ km and the projectiles can break the armor of a tank easily at a distance of 700 to 800 m, which is impossible for the bullets of an ordinary machine gun. (*Canadian Machinery and Manufacturing News*, vol. 44, no. 6, June, 1933, p. 16, *g*)

POWER-PLANT ENGINEERING

Removal of Solid Sulphur Compounds From Combustion Gases

THIS abstract is based on a paper entitled, "The Application to the Battersea Power Station of Researches Into the Elimination of Noxious Constituents From Flue Gases and the Treatment of Resulting Effluents," by G. W. Hewson, S. L. Pearce, A. Pollitt, and R. L. Rees, read July 11, 1933, before the Chemical Engineering Group Session of the annual meeting of the Society of Chemical Industry. Other contributions on the subject are listed in the original article, reference being made to the paper by Prof. H. F. Johnstone, of the University of Illinois, entitled, "Progress in the Removal of Sulphur Compounds From Waste Gases," read before the Fuels Division of The American Society of Mechanical Engineers.

In general, the method adopted at Battersea is to scrub the whole volume of combustion gases with a vast amount of warm water now admitted to amount to about 20 tons per ton of coal burned when the latter has not over 1 per cent sulphur, a figure below the average for British coals, followed by a final treatment with an alkali, such as lime or chalk mixed with water, removing 90 to 95 per cent of the total sulphur. Also, the scrubbing is carried out under such conditions that iron is present to act as a catalyst, while arrangements are included to remove water particles from the saturated gases, and to add heated air near the chimney base for "desaturation," presumably to prevent local deposition of rain at the chimney. All the scrubbing water, together with the sludge, is to be discharged to the river Thames.

The problem of sulphur elimination at Battersea is a difficult one because of the enormous scale of the operation. The paper gives a figure of 90,000,000 cu ft of gas per hr with a concentration of 0.02 to 0.05 per cent sulphur dioxide when burning coal containing 0.8 to 1 per cent sulphur.

The apparatus is both complicated and large. Its size may be judged from the fact that about 2660 tons of water per hour will have to be pumped for the sprays alone. The net capital cost of the whole gas treatment is given as £246,400, not including the 36 centrifugal dust separators. No operating costs are included.

Certain questions as to the operation of the apparatus are raised.

The following is cited verbatim: "A matter of the utmost importance also in this connection is why power stations only should be saddled with the costly operations involved in ridding combustion gases of acid-sulphur compounds. Obviously, the ideal is that all large users of fuel should operate with the completely innocuous chimney top, free from smoke, dust, and acid gases. For about half a century past the towns' gas industry has been carrying out a frenzied campaign against the use of electricity, first for lighting, and now for cooking, heating, and other domestic uses. In these circumstances, by what authority is a power station compelled to treat the chimney gases when a gasworks is apparently allowed a free hand not only to emit smoke, fumes, dust, and acid-sulphur compounds, but to pollute the whole atmosphere around with a foul smell of gas, and to cause endless trouble in the sewers and elsewhere with poisonous gas liquor?"

Hitherto, it has not been possible to absorb SO_2 on these lines like H_2S (sulphuretted hydrogen) as a commercial proposition. For example, certain ammonium salts absorb very large amounts of SO_2 when cold, not over 80 F, forming sulphites, thiosulphates, and other salts, but will only yield up part of it again on heating to, say, 200 F, and on present knowledge the method is too costly. (David Brownlie, *Steam Engineer*, vol. 2, no. 12, September, 1933, pp. 517–519, *d*. Compare *Mechanical World*, vol. 94, no. 2432, Aug. 11, 1933, pp. 769–772, liberally illustrated, for a description of the sulphur removal plant at the Battersea power station.)

RAILROAD ENGINEERING

Diesel-Electric Locomotives for Russia

CONDITIONS of railroad operation in certain parts of Russia are such as to make Diesel engines unusually attractive. Thus, for example, in certain parts of central Asia the trains make very long runs between stations with temperatures very high in the summer and very cold in the winter and under conditions in which water is lacking or is of the poorest quality. Moreover, the country is poorly developed and a considerable flexibility of railroad operation is necessary. An investigation has shown that Diesel-powered locomotives can give better performance under these conditions than present steam locomotives.

The first Diesel locomotive built for Russia in Germany and designed by Professor Romonosoff attracted world-wide attention. The present article describes another type recently built for Russia by Fried. Krupp Co., in Essen. The Krupp locomotive is said to be the largest and most powerful Diesel locomotive ever built in Germany. The unusually high atmospheric temperatures prevailing in the region where the locomotive is to be operated made it necessary to take this factor seriously into consideration in the design of all the machine parts. In particular, the Diesel engine with all of its accessories and the electrical equipment had to be so designed that air temperatures of 122 F should not affect the performance or operating reliability of the locomotives.

The original article gives the main dimensions of the locomotive in metric units.

The required output of 1650 hp is delivered by two Sulzer four-stroke-cycle Diesel engines each of the eight-cylinder single-acting precombustion-chamber type. Each motor is directly and rigidly connected to a direct-current generator. To save space, the shaft of the generator armature is direct connected to the Diesel-engine shaft without the intervention of any bearing, so that the generator has only one bearing of its own on the side of the armature away from the Diesel engine, while the exciter overhangs on the free end of the shaft. The Diesel engines are arranged parallel to the longitudinal axis of the locomotive and as far as possible to the sides of the engine room, thus providing a gangway between the engines.

The engines are so arranged that the generators are located not side by side but symmetrically to the cross-axis of the locomotive. To drive the five driving axles, double motors are used, this being the first time that such an arrangement has been employed in Diesel locomotives. These motors are held rigidly in the locomotive frame and their power is transmitted to the driving axles by means of a hollow shaft and Sécheron spring drive. (See Fig. 1.)

The pinions, located on the armature shafts, drive, with a transmission ratio of 1 to 6.8, the gear wheel which is attached to one end of a hollow shaft. This latter is located in the motor housing and encloses with a slight amount of play the axle of the driving wheel. The driving wheels are elastically connected to the hollow driving axles by a number of spiral springs.

The original article contains a circuit layout for operating the motors from the generators, the speed of the motors being regulated by the Leonard system. When normally connected, five half motors are fed in parallel from one generator. In

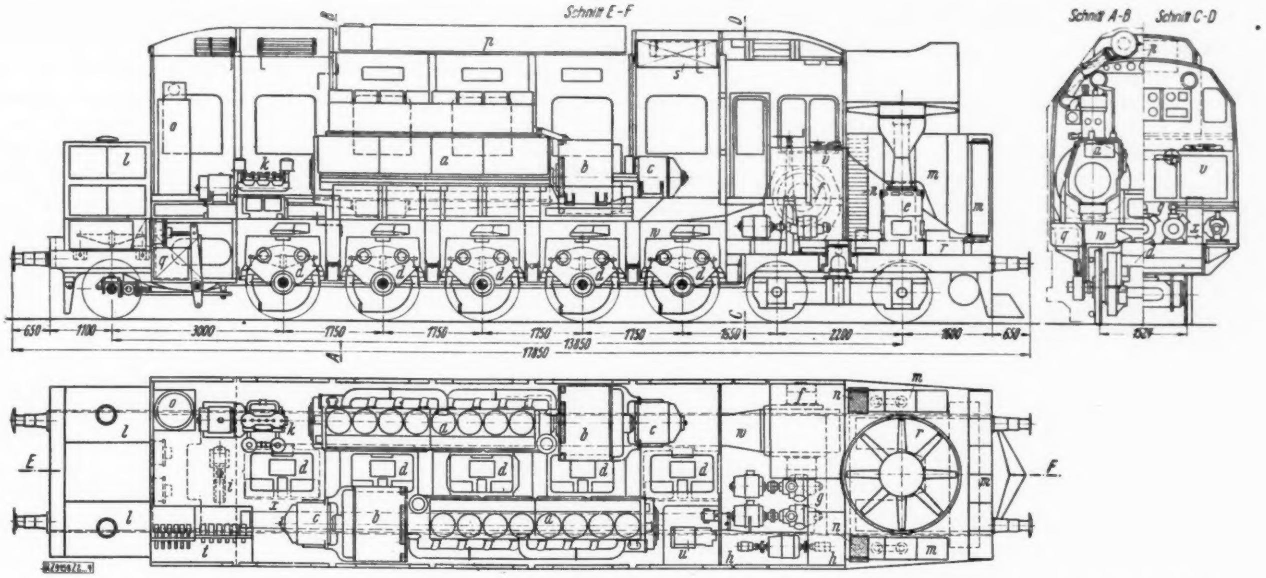


FIG. 1 SECTIONS OF THE DIESEL ELECTRIC LOCOMOTIVE BUILT BY KRUPP FOR RUSSIA (All the Dimensions Are in Mm)
(*a* = Diesel engines; *b* = generators (maximum voltage 800); *c* = exciters (normal voltage 150); *d* = double driving motors; *e* = air-cooler motor; *f* = ventilators for the driving motors; *g* = water-jacket pumps; *h* = oil circulating pumps; *i* = fuel delivery pump; *k* = air-brake compressor; *l* = storage batteries; *m* = oil and water radiator elements; *n* = air filter; *o* = heating boiler; *p* = exhaust stack; *q* = fuel storage tanks; *r* = water storage tanks; *s* = fuel supply tank; *t* = switch compartment; *u* = reversing switch; *v* = driver's panel; *w* = air tunnel; *x* = cable tunnel.)

order to prolong the life and more economically operate the Diesel engines, three operating speeds are provided, namely 460, 540, and 640 rpm, the lower speed of 460 rpm being used for idling only. The availability of two independent Diesel-electric groups, in addition to improving the reliability of operation, makes a more economical operation possible, as the locomotive may operate with two or only one engine, according to the load. The electrical hook-up for this operation is given in the original article. Several hook-ups are given and one of these shows all of the half motors connected in parallel to the generator. In such a case the motors work at normal speed, but at less than normal voltage. When, however, only one Diesel engine is in operation, only half the drawbar pull is available. In another hook-up, the two halves of the motors are connected in series with the result that each motor has only half of the voltage and runs at half speed, but can deliver its full drawbar pull. In addition to a shunt winding, the generators are provided with a compensated winding by means of which the output characteristics of the generator are made more adaptable to meet those of the Diesel engine, the regulation being improved in addition. This winding also makes it possible to connect the generators in the capacity of main motors to the storage battery for purposes of starting the engines.

In normal operation, the exciters of the generators are connected in parallel and feed a common 150-volt bus-bar. The same bar carries the shunt windings of the generators, the auxiliaries, and the storage battery. All the main electrical machinery as well as the various auxiliary groups for ventilation, cooking, etc., are controlled by electropneumatic switches. The controllers for forward and reverse operation, starting switches, and Diesel-engine speed controls are likewise electropneumatically operated from the driver's cab. Interlocking is provided to protect the machinery against an improper sequence.

The apparatus for cooling the jacket water and lubricating oil is located in front of the driver's cab. It is not quite as wide as the housing so that the driver can see on both sides past the coolers. The front and the two side walls of the cooler are made up of replaceable cooling elements consisting of vertical copper tubes of elliptic cross-section with the ribs drawn on. The cooling air is supplied by a fan which sucks it past these elements and discharges it into a smokestack-like structure. The motor driving this fan is supplied by current from the generator exciters and the hook-up is such that the fan can run at different speeds and deliver a variable output, depending on whether one or both Diesel motors are running.

Because it is expected that the locomotive will operate under greatly varying conditions of air temperature, provision has been made to cool the cooling water and lubricating oil to the desired temperatures only. The dimensions of the cooler and fan were so selected that the highest water temperature at 122 F air temperature should not exceed 194 F and that the maximum oil temperature should not go above 176 F when the engines are working at full capacity. Because of the prevalence of sand dust in the localities where the locomotives are to operate, both the combustion air for the Diesel engines and the air to cool the driving motors is passed through air filters provided with replaceable Delbag filter elements. The air passes through these elements on its way in and is then discharged into the atmosphere.

The mechanical details of the locomotive are given in the original article. At the rear end of the engine compartment is provided a heating boiler generating steam at 3 atm. pressure for heating the engine compartment and driver's cab. It can be heated either with the exhaust gases or by means of an oil burner. In very cold weather, particularly at starting, this boiler may be used for preheating the jacket water and the fuel. The fuel supply of 4100 kg (9000 lb) is sufficient for operating the locomotive at capacity for a period of about 16 hr. An electrically driven pump is provided for refilling the fuel tanks and the same pump is used to deliver the fuel from the storage tanks to the direct-feed tank located at a certain elevation. (E. Hagenbucher, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 77, no. 37, Sept. 16, 1933, pp. 1001–1004, 11 figs., *d*)

Diesel Railcars

SEVERAL Diesel mechanical units have been supplied by British concerns for use in Spain. Diesel traction in Spain commenced with three Diesel-electric cars for use on the Pamplona-San Sebastian Railway. The engines were supplied by the Beardmore Company and the vehicles have maintained all the passenger traffic over this 58-mile heavily graded line. Normal maintenance is carried out daily at each terminal by the drivers between arrival and departure. The oil filters are cleaned daily. The lubricating oil is drained from the sump after every 2500 km (1552.5 miles), that is, every fortnight, and after being filtered and treated, is replaced. This takes the driver and the laborer two hours to accomplish and an economy of 40 per cent in the lubricating-oil bill has been realized by this method.

Two Diesel mechanical cars were supplied to another line from Germany. Here the engine is mounted directly on the leading truck and drives the wheels through the medium of a four-speed gear box and connecting rod.

Still another Spanish railroad has a triple-car Diesel unit, in which the engine and auxiliary apparatus are mounted in a separate vehicle sandwiched between two passenger coaches with which it is articulated. The transmission from the engine is mechanical, through a four-speed gear box. Some trouble has been experienced on the numerous sharp curves, due to the rigid wheelbase.

The Northern Railway of Spain gave an order for ten Diesel mechanical cars to the Geathom Company, a combination of various firms interested in Diesel traction. Seven of these ten cars are for mechanical transmission and three electrical. (*Diesel Railway Traction*, supplement to *The Railway Gazette*, June 16, 1933, pp. 8–9, illustrated, *d*)

Gardner-Edwards Diesel railcars have been brought out in two new designs. The first is a 26-seat railcar with separate engine and luggage compartments and can be arranged for driving from either end. The second and larger vehicle is a 30-seat car designed for one-man operation and arranged for driving from one end only. The cars can be equipped with single or twin engines, high speed, medium speed, and low speed. Performance figures for two types are given in the original article. (*Diesel Railway Traction*, supplement to *The Railway Gazette*, June 16, 1933, p. 10, illustrated, *d*)

In France the P.L.M. Railroad has bought a semi-streamlined Diesel railcar. The driver's cab and the Diesel engine are situated in the center part of the vehicle. The former is raised and the latter sunk in relation to the car frame, which is electrically welded throughout. By means of this construction, neither engine nor driver obstructs the passengers' view or encroaches upon the passenger-carrying space of the vehicle. The ends of the car are slightly rounded, and the general lines have been designed with the object of minimizing head resistance.

Efficient braking is insured by an L. B. Jourdain Monneret hydraulic brake, acting either alone or in conjuction with a four-shoe electromagnetic rail brake. With this double braking, the car can be brought to rest from a speed of 64 km per hr (39.7 mph) in about 30 m (98.4 ft) although during the trials the best pull-up from this speed was in 26 m (85.2 ft). Such powerful braking is a great asset in enabling very high average speed to be attained with safety, since full speed may be maintained up to within a very short distance of the stopping place. It insures, furthermore, a high measure of safety, which is enhanced by the location of the driver in his raised cab where he has an excellent view of the track. When approaching an unattended grade crossing, it is sufficient for the driver to slow down from 90 km per hr (56 mph) to about 60 km per hr (37.2 mph), for he is able to pull up from this speed in about 30 yards if, as he approaches a grade crossing, he sees other vehicles about to cross. (*Diesel Railway Traction* supplement to *The Railway Gazette*, June 16, 1933, p. 4, illustrated, *d*)

In the Maybach Diesel-engined railcar a six-cylinder engine is used. The special shape of the oil sump enables the transmission shaft between the engine and the gearbox to pass horizontally underneath the bogey bolster, and permits of placing the engine lower in the bogey frame than formerly, thus economizing head room. The operation of the various change-speed and reversing gears is effected by oil pressure, the power of the engine being transmitted to the gearbox by a Vulcan "fluid flywheel" hydraulic coupling. With this coupling, immediately the first gear is engaged the vehicle commences to move forward smoothly and gathers speed smoothly and rapidly as the slip in the fluid coupling decreases.

The pressure oil, by means of which gear changing and reversing are effected, is provided by a small pump, which is chain-driven off the transmission equipment of the bogey. A special brake, operated by oil pressure, is provided in order to hold the secondary shaft of the gearbox during the transition of the reverse sleeve from one bevel wheel to the other. The oil supply to the brake cylinder is controlled by the reverse sleeve, and severe shocks, which are likely to damage the gears, are thus avoided. (Roderick Hedley, *Diesel Railway Traction*, supplement to *The Railway Gazette*, June 16, 1933, p. 5, illustrated, *d*)

Tests on the Piston-Valve By-pass

A TEST was made of the performance of the piston-valve by-pass of the 9600-type locomotive which was devised by the Machinery and Rolling Stock Section, Tokyo Region. Further, an investigation was carried out into the air resistance produced in the steam cylinder when this device was applied, as compared with that produced when an ordinary by-pass or both these by-passes were used on the locomotive running with the steam being cut off. A comparative study was also made on the variation of steam pressure occurring while the locomotive was run under steam admission. The results of these investigations, which are given in this paper, may serve as a guide to locomotive operation and designing. (*Bulletin*, Research Office, Japanese Government Railways, Tokyo, vol. 21, no. 23, July 25, 1933, illustrated, in Japanese, *e*)

REFRIGERATION ENGINEERING

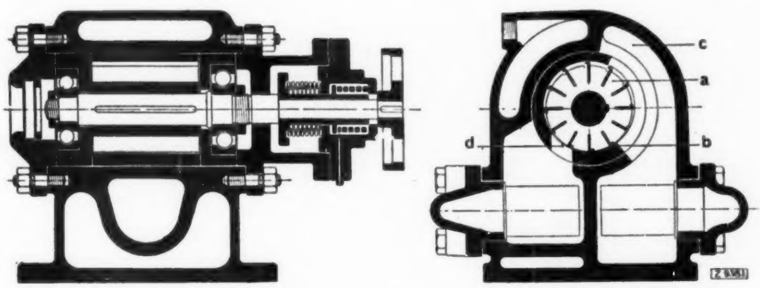
Sulzer "Frigorotor"

THIS UNIT is intended for domestic use and such apparatus of small and medium capacity as is used in hotels, restaurants, meat and fish stores, etc. This means a unit with an output of from 20,000 to 100,000 Btu per hr. In order that the cold may be conveyed under the simplest conditions, preference has been given to indirect refrigeration. The cold produced is transmitted to a liquid which is circulated in the piping by means of a pump contained in the apparatus generating the cold. A compressor with condenser and evaporator in combination with the distributing and circulating piping constitutes the new system of central refrigeration. As regards the refrigerating agent, ammonia has been selected.

The compression of ammonia in a rotary machine presented a series of problems which required considerable experimentation, but these, it is claimed, have been solved. The ammonia compressor, Fig. 2, has a shaft carried in ball bearings running in an

oil bath and supporting a drum or rotor *a*. The stationary part *b* of the body of the compressor is not concentric with the rotor *a* and consequently a crescent-shaped space is formed between these two cylindrical bodies; the rotor carries grooves in which the movable blades, that subdivide the space into a certain number of cells or stages of compression, can slide. Centrifugal force keeps the blades constantly in contact with the inner surface of the liner of the compressor.

The cells situated beside the suction chamber *c* increase in volume in proportion to their displacement, and the ammonia gas is drawn from the chamber *c* through ports provided in the liner *b*. As soon as a cell has attained its maximum capacity, communication with the suction chamber *c* is shut off, and the volume of the cell then decreases, the vapor in it being compressed to a pressure corresponding to the saturation temperature of the condenser. The vapor then escapes through ports into the compression chamber *d*, from whence it passes to the condenser. After having passed the discharge ports, the cells of the rotor pass the sector included between the compression chamber and the suction chamber. This section is kept gas-tight by oil under pressure, cutting off all communication between the compression and suction chambers. The oil also insures the cells being gas-tight with respect to each other, and the shaft with respect to the atmosphere, and at the same time ample lubrication provides for all rubbing surfaces. The quantity of oil fulfilling these functions is many times the quantity used in reciprocating compressors. Care has been taken to keep the peripheral speed of the rotor at very conservative values.



a Rotor *c* Suction chamber
b Adjustable liner *d* Compression chamber

FIG. 2 LONGITUDINAL AND CROSS-SECTION THROUGH A "FRIGOROTOR" AMMONIA COMPRESSOR WITH RATED CAPACITY OF 102,000 BTU PER HR

The ammonia condenser and the evaporator for cooling the brine are both of the tubular type. The evaporator is equipped with a float regulator which maintains the liquid ammonia within the evaporator at a level corresponding to the maximum efficiency of the apparatus, thus fixing a certain temperature of superheat for the ammonia vapor drawn in and also preventing any liquid ammonia from being drawn into the compressor. The evaporator and condenser are formed by two concentric cylinders, arranged in such a way that the condenser, which is of annular cross-section, surrounds the evaporator, the two units being insulated from each other by cork.

Lack of space prevents a description of the other details of the apparatus. Particular attention is called, however, to the passage dealing with the method of specifying the refrigerating capacity of compressors. It is stated that the purchaser of refrigerating machinery will be well advised to choose the refrigerating capacity of his compressor in such a way that the refrigeration required in summer can be produced by running the compressor for not more than 10 to 12 hr daily. (Ju., *Sulzer Technical Review*, no. 3, 1933, pp. 1–11, 13 figs., *d*)

SHIPBUILDING

Stoker- and Pulverized-Coal-Fired Steamships

AN IMPORTANT contract for three train-ferry vessels for the Dover-Dunkirk run has been placed by the Southern Railway Co. Like other railroads who built train ferries recently, the Southern installed mechanical stokers. The experience of other operators has shown that the technical problems which for a time required the development of a satisfactory marine mechanical stoker have now been largely overcome, and the fact that such stokers are being fitted in railway ships which run to exacting schedules is significant.

Another recent order to which reference may be made is that for the steam generating plant of the vessel under construction at Hong Kong for the China Navigation Company for which Scott's Shipbuilding & Engineering Co., Ltd., are supplying the propelling machinery. This steam plant will consist of two Babcock & Wilcox boilers, fitted with superheaters and air heaters, and to be fired by Erith-Roe stokers. These boilers will work at 230 lb per sq in. pressure and 600 F final temperature, and will burn Chinese coals.

It is stated in addition that the more difficult, and to some extent unexpected, problems in using pulverized coal on shipboard are being gradually overcome, and very satisfactory results are being achieved on the vessels of the Liverpool-Harrison line and on some Japanese vessels. In the Harrison steamships the comparative economy over hand firing in sister vessels is of the order of 24 per cent, while in the Japanese *Johore Maru* with 13-knot service speed and with a triple-expansion engine and exhaust steam turbine, the coal consumption works out at 1.16 lb per ihp-hr in service.

As is the case of mechanical stokers, the furnaces of water-tube boilers which are relatively larger than those associated with Scotch boilers are better suited for obtaining the best results for pulverized-coal firing, although it is a peculiar circumstance that the majority of sea-going pulverized-coal installations are used with Scotch boilers.

The original article contains some arguments in favor of using coal on British ships. (*The Shipbuilder and Marine Engine-Builder*, vol. 40, no. 281, August, 1933, editorial on pp. 371–372, *g*. A description and data of trials of *Johore Maru* will be found on pp. 391–394 and plates 17 and 18 of the same issue.)

TESTING MACHINERY

750-Ton Chain Cable and Anchor Testing Machine

THE ever-increasing size of passenger and cargo vessels has brought about the installation by Lloyds British Testing Co., Ltd., of a testing machine constructed to the specification of the British Board of Trade and capable of testing chain cables and anchors necessary for the largest vessels yet contemplated, as well as steel wire ropes and similar articles. The overall length of the machine is 178 ft 6 in., and the total weight about 250 tons. Part of the machine is sunk below the floor of the test house to facilitate the handling of heavy specimens.

The straining portion comprises a large cylinder and ram of the single-acting type for applying the strain and a smaller cylinder and ram also of the single-acting type for returning the main ram and attachments to position after test. The

main cylinder is designed for an accumulator pressure supply of 2 tons per sq in. and the return cylinder for a pressure of $^1/_2$ ton per sq in. As it is not anticipated that the machine will be regularly required for testing loads near its full capacity, an inner ram has been provided to operate inside the main ram which then functions as the cylinder. In this way, a saving of pressure water is secured. When the machine is used at the lowest capacity, the main ram is locked in its innermost position in the main straining cylinder by means of shear pins in the upper and lower die bars secured to the straining and return cylinders.

The main straining ram is 24 in. in diameter and the inner straining ram 12 in., the stroke of either being 9 ft. To prevent corrosion and to permit pressure maintenance, the main and inner straining rams have been surfaced by the Fescol process with electrically deposited nickel. (The details of the Fescol process have never been published. For further information about it, see MECHANICAL ENGINEERING, vol. 50, no. 6, June, 1928, p. 481.) (*The Far Eastern Review*, vol. 29, no. 4, April, 1933, pp. 179–180, 3 figs., *d*)

TESTING AND MEASUREMENT

Measuring Oil Consumption

THE difficulty of obtaining accurate results in oil-consumption tests is pointed out. If short tests are made, differences in completeness of drainage are sufficient to make accuracy well-nigh impossible If longer runs are attempted to reduce the influence of variations in the completeness of drainage, then the ever-changing mechanical condition of the engine becomes a factor. Sticking of the compression rings and carbonization of the drain holes in the oil-control rings cannot be determined without opening up the engine, and the abrupt change in mechanical fits resulting from opening up of the engine and removing deposits from pistons and rings affects the results.

The authors claim to have developed a quick, accurate, and easily checked oil-consumption test. The dry-sump system is used with external oil reservoirs and external pumps driven by small variable-speed electric motors. Three reservoirs are used and a three-way valve permits the pressure pump to draw oil from the selected reservoir, while the scavenging pump returns the oil to the reservoirs through a swiveled discharge pipe. The baffles and screen are removed from the oil pan of the engine so as to permit the oil in the crankcase to drain freely toward the outlet. The pressure relief valve is also eliminated. Control of the pressure on the oil which is delivered directly to the main lead is obtained by varying the speed of the electrically driven pressure pump. The rate of delivery of oil to the engine is measured by a small venturi meter in the line. The oil temperature is accurately controlled.

In the development of the test it was found that the rate of oil consumption depends to a great extent on the mixture ratio, and even a slight change in mixture ratio resulting in changes from barometric pressure has a noticeable effect. To eliminate this variable, the carbureter is surrounded by a box in which a definite air pressure is maintained by means of a throttle. It is claimed that different oils may be compared with those set up and the effect on oil consumption of almost any condition of operation can be measured accurately and quickly. The details of the test are given in the original article. (Paper by J. P. Stewart and T. H. Risk, Socony Vacuum Corporation, before the Automotive Engineering Congress, Chicago, Aug. 28 to Sept. 4, 1933, abstracted through *Automotive Industries*, vol. 69, no. 9, Aug. 26, 1933, pp. 235–236, *d*)

THERMODYNAMICS

Mean Temperature Differences in Multipass Heat Exchangers

THE mean temperature difference in multipass heat exchangers may be calculated by means of charts presented in this paper. These charts give correction factors by which the logarithmic mean temperature difference for counterflow may be multiplied to give the mean temperature difference for multipass exchangers. These correction factors depend only on the number of passes in the exchanger and on certain dimensionless ratios involving the inlet and outlet temperatures of the two fluids. The derivations of equations for mean temperature difference are given in detail for the exchanger having one pass shell-side and two passes tube-side, and for the exchanger having two passes shell-side and four passes tube-side. The assumptions involved are those made in the derivation of the logarithmic mean temperature difference plus the additional assumption of good mixing of the shell-side fluid. (W. M. Nagle, Mass. Inst. of Technology, in *Industrial and Engineering Chemistry*, vol. 25, Industrial Edition, no. 6 (consecutive no. 19), June, 1933, pp. 604–609, *m*)

VARIA

The Sheet-Metal Trade and Plastic Materials

THE following is part of an editorial discussing the possibilities of competition between the sheet-metal and plastic trades, in which the plastic materials are now on the offensive.

At a recent meeting the chairman of the plastic group of the Society of Chemical Industry indulged in some speculation in respect to the future of this industry. Its present turnover is estimated at 20,000,000 per annum, and he forecasts the possibility of the production of such products as automobile bodies, boats, ships, and so on. This is doubtless looking a long way ahead, but those associated with the sheet-metal industries would be well advised to watch the development of this type of material. It obviously lends itself to the production of articles on mass lines, that is, repetition products, and there is at present obviously a limit to the size in which a single article can be produced. The demand will have to be very large to justify the cost of the necessary dies, and it is understood that the articles cannot yet be produced by pressing. Whether these materials, in combination with asbestos or some similar material, could be produced in sheet form and pressed to shape, as are ordinary metal products remains to be seen.

In our view, there is no need for the industry to credit the possibility of any serious inroad into the sheet-metal trade. History has shown over and over again that a new product of this kind makes its way slowly and finds its own field, and develops alongside existing materials. It must also be borne in mind that the origin of these synthetic resins goes back now for some quarter of a century. (*Sheet Metal Industries*, vol. 7, no. 76, August, 1933, p. 200, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

CHARLES PIEZ, 1866–1933

CHARLES PIEZ, chairman of the board of the Link-Belt Company, Chicago, Ill., and Past-President of The American Society of Mechanical Engineers, died of pneumonia on October 2, 1933, at the Garfield Hospital, Washington, D. C. Mr. Piez's health had been failing for the past five years, and since February, 1932, he had been inactive in business. Last May he moved from Chicago to Washington, and had recently been the President's dinner guest at the White House.

Mr. Piez had served the Link Belt Company and its predecessor, the Link-Belt Engineering Company, ever since his graduation from Columbia University in 1889. His career was thus coincident with the great developments in material-handling and conveying machinery that have become such characteristic features of production and labor-saving methods for which this country is now noted. It was another A.S.M.E. past-president, James Mapes Dodge, who saw the possibilities of developing the link belting invented by William D. Ewart, of Chicago, and joined with him, in 1888, in the establishment of the Link-Belt Engineering Company, in which Mr. Dodge carried out his ideas along strictly engineering lines and with a highly specialized engineering staff. Mr. Piez came under the influence of this environment within a month of his graduation from Columbia. Starting as a draftsman, he served successively as chief draftsman, chief engineer, general superintendent, general manager, president, and, from 1924 to February, 1932, chairman of the board. His career illustrates in a spectacular fashion how the technical graduate with capacity for executive responsibilities and a flair for the financial and non-engineering aspects of industrial life passes into a position of leadership in business following a helpful and necessary experience in the rigid discipline of engineering design and production. His estimate of the value of an education in engineering is contained in an address delivered at Akron, Ohio, in the Fall of 1929, in which he said:

CHARLES PIEZ

"If I had my life to live over again, I am certain that I would start it with a course in mechanical engineering, because that represents the best means of acquiring a broad foundation for a useful, practical life, one that not only provides opportunities for a professional career, but also affords abundant opportunity for success in a business career.

"This is true because engineering training develops the ability to dig up and properly weigh the facts before reaching a conclusion, and this ability is the basis of sound judgment in every walk of life."

As the chief executive of a large industrial enterprise, Mr. Piez had an opportunity to appraise the value of sound management principles. In a message to the members of The American Society of Mechanical Engineers, assembled in Washington in April, 1930, to celebrate the founding of the Society, Mr. Piez wrote: "It has been in large measure due to the engineer that management has been raised to the dignity of an art, and that it is now generally recognized as the most important factor in the conduct of industry."

He sensed keenly the progress that engineering has made in recent years toward a broader understanding of its economic possibilities and responsibilities. Unable, because of illness, to deliver the customary presidential address to the A.S.M.E. in December, 1930, he telegraphed his greetings and concluded with these words of high hope and far-sighted vision. "The A.S.M.E. ought to make itself a commanding factor in every field of mechanical engineering, for the profession has for its domain not only the strictly technical problems of industry, but the economic problems as well. There are glorious opportunities ahead. It is for our successors to embrace them."

Largely as a result of his ability as an organizer and manager, Mr. Piez was selected by Edward N. Hurley, then chairman of the U. S. Shipping Board, in November, 1917, to be vice-president and general manager of the Emergency Fleet Corporation. As the chief executive of this enterprise, and later succeeding Mr. Schwab as director general, Mr. Piez advised upon and directed the expenditure of three billion dollars. He had control over 600,000 persons employed in the shipyards and fabricating plants, and in industries furnishing supplies to the yards.

Mr. Piez joined the Emergency Fleet Corporation in its earlier days, and the character of the organization, its personnel, and its methods in accomplishing the great task assigned to it in the War, were largely his. Mr. Schwab, when leaving the Emergency Fleet Corporation, said of Mr. Piez: "I regard you, above all other men, as having contributed more to the work done in the Fleet Corporation than any one else."

Mr. Piez resigned on May 1, 1919, as director general, to return to his former business. He continued as president of the Link-Belt Company until 1924, when he became chairman of the board, and was active in this position until February, 1932.

Mr. Piez served as president of the Commercial Club of Chicago. His periods of service as president of the Illinois Manufacturers' Association were from 1911 to 1913 and again from 1924 to 1925. He was a director of the Drexel State Bank of Chicago; director, Illinois Bell Telephone Co.; a member of the Executive Committee of the Museum of Science and Industry founded by Julius Rosenwald. He received the honorary degree of doctor of commercial science from New York University. He was a member of the following engi-

neering societies: American Institute of Mining and Metallurgical Engineers, Society of Naval Architects and Marine Engineers, Western Society of Engineers, and Engineers' Society of Northeastern Pennsylvania. He became a member of the A.S.M.E. in 1894, and was elected to the presidency in the Fall of 1929. His term was coincident with the Fiftieth Anniversary of the Society, but failing health made it impossible for him to attend the celebrations in New York and Washington, and the Annual Meeting in 1930.

Mr. Piez was instrumental in framing much of the labor legislation of the State of Illinois, having been a member of the commission that drew the State Factory Act. He was chairman of the Workmen's Compensation Commission, and a member of the State Arbitration Board, State of Illinois.

Mr. Piez was born on Sept. 24, 1866, at Mayence, Germany, the son of Jacob and Catherine Liebig Piez, naturalized American citizens who emigrated to the United States while he was a boy. He was graduated from the School of Mines, Columbia University, in 1889, with the degree of engineer of mines. He is survived by his wife, Mrs. Laura Sadler Cocke Piez, of Laurel, Md., whom he married in 1920, and by his sister, Miss Ernestine Piez, of New York City.

Mr. Piez was a member of the Chicago, University, Commercial, and Flossmoor Country clubs of Chicago, the Union League Club of Philadelphia, and the Chevy Chase Club of Washington. He was a Republican and a Mason.

CORRESPONDENCE

READERS are asked to make the fullest use of this department of "Mechanical Engineering." Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Engineer or Clerk

TO THE EDITOR:

John H. R. Arms, employment agent, displays himself as quite a campaigner for new members under the above heading in the August issue of MECHANICAL ENGINEERING (p. 518). However, I would say that his suggestion of "professionally minded" works both ways and I know that many of us members would like to have this suggestion extended to the administration of the Society, and this is the very point to which members and past members refer to when we say "not getting anything out of it."

There seems always to be money for big social affairs, etc., but there is not a cent for real technical contributions to our Journal, that is, for articles for which the really professionally minded engineer is looking and as we find them in the journals of other engineering organizations the world over.

For years I have been writing on this subject with other members and officers of the Society. Everybody sees this point, except 29 West 39th Street, and therefore, there is no change in its policy, but it seems to me a man must be unfamiliar with engineering problems or, better, unfamiliar with daily problems in the engineering profession that he could say the men who left our Society are not sufficiently "professionally minded" when, as a matter of fact, the shoe is on the other foot.

H. SCHRECK.[1]

Corning, N. Y.

TO THE EDITOR:

The Committee on Publications, which, under the direction of the Council, governs the publication policy of The American Society of Mechanical Engineers, is always pleased to receive comments from members on publication policies.

Mr. Schreck refers to expenditures for social affairs. While these are not under the jurisdiction of this Committee, I am informed by the Committee on Meetings and Program that such expenditures are limited to the expense of the President's reception amounting to not more than a few hundred dollars. All other social events are self-supporting.

As to the technical papers contributed for publication, several hundred presented under the auspices of the Professional Divisions of the Society are reviewed by experts, by the Divisions, and by the Committee on Publications. Of these, 141 appeared in the Transactions of the Society for 1932, the last volume for which figures are available. For the printing and distribution of the Transactions in 1931–32, $45,591.20 was spent. The figures for the current fiscal year will be approximately $30,000, while next year, despite the necessary reduction in income, the Council has directed that $19,000 be spent for this purpose.

At the present time a Special Committee on Policies and Budget is engaged in formulating the policies of the Society and in focusing its aims and objectives. Comments from A.S.M.E. members will be welcomed by the Committee on Publications and by the Special Committee on Policies and Budget for use in this new program.

L. C. MORROW.[2]

New York, N. Y.

Control of Overproduction

TO THE EDITOR:

One of the most difficult points in national recovery is the determination of the proper balance between the manufacture of commodities which are consumed, and manufacture of equipment and buildings for the production of manufactured commodities. Inasmuch as these latter are not consumed in the same sense as are commodities, they are frequently called "durables" or "capital goods."

The reconciliation of these two classes of industry is a most difficult problem inasmuch as their interests are almost always

[1] Mechanical Engineer, Ingersoll-Rand Co. Mem. A.S.M.E.

[2] Chairman, Committee on Publications, The American Society of Mechanical Engineers.

antagonistic. Thus some of the first commodity codes accepted by the National Recovery Administration had very stringent limitations of new plants or equipment, although the later codes have eliminated or greatly modified this type of control.

It must be borne in mind that there are usually as many workers producing capital goods as there are producing commodities, hence if we are to stop overproduction by preventing the building of new plants and equipment, we are, in theory anyway, forever keeping 50 per cent of our workers jobless. This 50 per cent number is modified only by deducting therefrom those workers who could be employed on public works.

It would seem as though a fair method of control could be placed into effect by simply requiring an honest system of handling depreciation, and carrying the theory of depreciation through to its ultimate conclusion. In brief, this proposition simply calls for the setting aside, as at present, of a fund for depreciation, and isolating this fund in such fashion that when the plant has been fully depreciated, the fund will be used for the building of a new plant instead of diverting it to the numerous other corporate outlays, such as dividends or advertising, as is now so frequently done. This building may not be all done at once, but parts of the depreciation fund may be used from time to time to rebuild equipment or to substitute new equipment, and when so taken away from the main depreciation reserve, will be counted as a fair and proper use.

This will be of little avail, however, unless the machinery that has become depreciated is actually scrapped as useless—broken up—not merely sold to another company or kept in place and operating. By scrapping is meant demolition—rendering unfit for use. We talk a great deal about having too many plants, but in most cases these plants are obsolete. The selling of obsolete equipment to a competitor or to another person to start up in competition with the plant selling the equipment is very poor policy, although the opportunity of apparently realizing a little cash thereby is actually and usually eagerly grasped.

The basis of control is simply by income-tax deductions. The Government can so arrange it as not to allow depreciation unless that depreciation is not only carried as a separate fund but actually used at the end of the period for the replacement of equipment in the fashion mentioned and for no other purpose. Machinery fully depreciated will be scrapped and not sold for a salvage value that, although small, does a great deal of harm to the industry as a whole.

The amount of obsolete equipment in use may be guessed at by the fact that a normal depreciation rate for equipment is 10 per cent, that is, an estimated life of 10 years. In the past four years there has been substantially no plant rebuilding; a great proportion of the plant capacity now operating was built before 1923.

This scheme is not wholly chimerical, as it has been put into effect in one industry by the writer where all obsolete machinery has been broken up. In fact, the writer's company has not only done this, but in one instance where it purchased a bankrupt plant, it turned down offers for the salvage of the equipment, and actually broke up every piece of it except a couple of sample machines which were kept for the historical exposition of the industry in a museum.

Should overproduction still confront the industry, in spite of proper depreciation rates, then comes the next step, that of licensing plants in the public interest and thus prohibiting too great a flow of capital into the industry. The basis of granting licenses in a territory or within a class of manufacture may well be to protect the newer and better plant and leave without protection the older and more nearly obsolete. This will also enable the industry to present better competition to the industries which are seeking to invade its field, for we must not forget that not only is there "intra-industry" competition between plants in the same industry, but also inter-industry competition between products.

Licensing of manufacturing plants, thus tending to give them a status similar to utilities, would indeed be a calamity in the minds of many economists, and its mention here is not an advocacy, but merely a pointing out that this control by "honest taking of and use of" depreciation does not interfere with either free flow of capital or with licensing, and in fact may defer the latter or eliminate its desirability.

Depreciation, of course, is deductible only against profit or surplus; when both are absent, full depreciation must needs be deferred.

CROSBY FIELD.[3]

Brooklyn, N. Y.

An Important Contribution to Graphical Methods

TO THE EDITOR:

Almost every engineer has occasion at times to represent three-dimensional objects on a plane, and more often to make use of such presentations made by others. A practical criterion for a good plane representation has usually been taken to be that, when properly placed, it should produce upon the retinal surface of the eye the same image as that produced by the object itself. The more nearly plane representations of this character satisfy this criterion, the more readily should we expect the observer thereof to visualize the original object.

Not only do scientists and engineers appeal to such methods of representation in connection with the presentation of a picture of an object, but also in the presentation of a picture of an idea or conceptual object, such as an atomic model, a dynamic surface, a frequency surface, an ideal stress-strain diagram, etc. The extensive use made of plane figures to represent three-dimensional space figures, indicates the breadth of interest in the graphical problem of making such a representation that will satisfy the previously mentioned criterion.

Naturally, the engineer who wishes to picture either some three-dimensional object or some three-dimensional concept on a plane is interested in knowing how he can do this satisfactorily. In other words, he wishes to know the *rules* of effective presentation. Similarly, engineers and scientists who have occasion to interpret such figures are likewise interested in having these representations made in such a way as to present accurately the object that the plane figure is supposed to picture. Perhaps few people have greater interest in the rules for effective presentation of this character than do the editors of scientific and engineering journals.

For some time members of the Committee on Standardization of The American Society of Mechanical Engineers have realized the great need for improvement in the technique of graphical methods. Accordingly, in 1926 they inspired the calling together of representatives of many scientific and engineering societies to organize, under the procedure of the American Standards Association, a sectional committee on Standards for Graphic Presentation. Soon thereafter, a Subcommittee on Engineering and Scientific Graphs was organized. To this subcommittee fell the problem, among others, of attempting to

[3] Vice-President, Brillo Mfg. Co., Inc., President, Flakice Corp. Life Member A.S.M.E.

specify a standard procedure for the preparation of effective plane representations of space figures. The subcommittee soon discovered, however, that with this problem, as with many of the others, much had to be done before the requisite so-called standard procedures could be proposed. In such cases it was decided that one of the first things for the Committee to do was to sponsor the preparation of a critical treatise giving the theoretical background for the preparation of rules of procedure to meet specific kinds of practical problems.

Of course, effective representation in a plane of a three-dimensional figure is usually considered a part of the subject of descriptive geometry. The subcommittee was fortunate in having as one of its members Prof. William H. Roever, a representative of the American Mathematical Society on the Committee, and an internationally recognized authority in this field. He undertook the preparation of the requisite treatise. The first part of this treatise has just been published by The Macmillan Company, New York, under the title, "The Mongean Method of Descriptive Geometry."

In this treatise Professor Roever not only surveys the various methods which have been devised for the purpose of effectively representing a space figure in a plane, but also treats the other outstanding problem of descriptive geometry, namely, the solution of problems of space by means of constructions which can be executed in a plane. Although historically the solution of such problems of space in this manner grew up in the particular fields of stone masonry and architecture, nevertheless it has a very important bearing on the proper interpretation of a plane figure supposed to represent an object in three dimensions. Naturally, the engineer is interested not only in the perceptual appearance of a figure but also in the quantitative relations which he is supposed to see in that representation.

W. A. SHEWHART.[4]

New York, N. Y.

How Do You Think?

TO THE EDITOR:

I was very much interested in reading the article by George M. Eaton[5] in the May issue of MECHANICAL ENGINEERING.

It is to the credit of Mr. Eaton that he gave a table containing the steps on the procedure which he follows for the sake of efficiency in solving engineering problems. He offers his pattern rather reluctantly, advising every one to make his own. However, I do not think he should feel that way. His pattern is fundamentally correct and, if intelligently used, will render a good service.

Independence of reasoning must be understood as a conscious effort to avoid the repetition of another person's errors. This course of independence does not necessarily lead toward truth, because one whose errors differ from those of others may be an independent thinker. I believe it is much more important to reason straight or right than to be simply independent. Independence is a virtue in the process of learning but not in producing. We learn by the mistakes of others and learn still more and better by making our own errors. However, if we assume for a moment that there is a right way of approaching and solving a problem, and if we agree that we have found a right way, then why should we preach independence? Simply because somebody has said that we cannot reason by rules? Following this saying certainly cannot be called independence.

The greatest achievement of the human race—science—was made possible because we have stuck religiously to a few rules of reasoning. The first rule is: Proceed systematically with proof at each step; the second, observe, infer, and verify. There are more rules that make the scientific procedure of investigation or the so-called scientific method. Certainly, no one will preach independence from the scientific method.

L. A. TROFIMOV.[6]

Cleveland, Ohio.

TO THE EDITOR:

I am unable to accept Mr. Trofimov's belief that my modest plan of thinking should be taken at face value by others, without an attempt to make a better plan. This plan, as I stated in the article in MECHANICAL ENGINEERING, refuses to stay put very long for me.

Since the apparently logical procedure of highly trained minds leads so often to conclusions which fail to resist the acid test of time, I am obliged to continue to worship at the shrine of independence of thought, not just because it is independent, but because so few products of any mind prove to be so fundamental that they are not worn down by the products of other minds.

GEORGE M. EATON.[7]

Ambridge, Pa.

A.S.M.E. Boiler Code

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretation of this Committee in Cases Nos. 727 (Reopened), 756 to 760 as formulated at the meeting of September 14, 1933, all having been approved by the Council. In accordance with established practise, names of inquirers have been omitted.

CASE No. 727 (Reopened)

Inquiry: In the application of a fusion-welded nozzle which requires stress relieving, to a Class 2 unfired pressure vessel which is not required to be stress relieved, is it permissible to heat locally the nozzle and an annular ring of the shell or head around the nozzle?

Reply: It is the opinion of the Committee that recent experience justifies a modification of the original reply in this Case so that on Class 2 vessels, nozzles or welded attachments for which stress relief is required may be locally stress relieved

[4] Chairman, Subcommittee on Engineering and Scientific Graphs, A.S.M.E.

[5] "How Do You Think?" MECHANICAL ENGINEERING, May, 1933, p. 279.

[6] Development Engineer, The Electric Controller & Mfg. Co.

[7] Director of Research, Spang, Chalfant & Co., Inc. Mem. A.S.M.E.

by heating an annular ring around the nozzle or attachment, provided any part of the welded edge thereof is not less than $12t$ (t = thickness of plate) from the nearest adjacent welded joint or other element that would tend to restrict the free expansive movement of the heated area. The outside dimensions of this annular ring to be heated shall be at least $6t$ away from the outermost weld but not less than 5 in., and the entire area shall be heated simultaneously.

CASE No. 756

(In the hands of the Committee)

CASE No. 757

(In the hands of the Committee)

CASE No. 758

(In the hands of the Committee)

CASE No. 759

Inquiry: Par. U-59*b* is not quite clear as regards the stress relieving of connections attached by welding to riveted vessels that are used in Class 3 service. Do such connections require to be stress relieved?

Reply: It is the opinion of the Committee that under the requirements of Par. U-59*b* connections attached by fusion welding to riveted vessels used in Class 3 service are not required to be stress relieved. However, all the provisions for welding nozzles in Class 3 welded vessels must be complied with and the vessels shall be stamped Class 3.

CASE No. 760

Inquiry: Is it permissible to use cast steel in water heads, shell heads, and floating heads of unfired pressure vessels, and what is the allowable working stress therefor?

Reply: It is the opinion of the Committee that under the terms of Par. U-12, cast steel may be used for water heads, shell heads, and floating heads of unfired pressure vessels with an allowable working stress of 7000 lb per sq in.

BOOK REVIEWS AND LIBRARY NOTES

Chemical Engineering Progress

TWENTY-FIVE YEARS OF CHEMICAL ENGINEERING PROGRESS, 1908–1933. Silver Anniversary Volume of American Institute of Chemical Engineers. Edited by Sidney D. Kirkpatrick. Published for the Institute by D. Van Nostrand Co., Inc., New York, 1933. Cloth, 6 × 9 in., 373 pp., diagrs., charts, tables, $4. For sale through Office of the Executive Secretary, Bellevue Court Bldg., Philadelphia, Pa.

REVIEWED BY GEO. A. ORROK[1]

TWENTY-FIVE years of chemical engineering achievement in America in virtually all branches of the industry is summarized in the twenty-five essays by recognized authorities comprising this volume, published by the American Institute of Chemical Engineers on the occasion of the Silver Anniversary of its founding in 1908. Individually each essay reviews the progress made during the last quarter century in a definite industrial field. Collectively they portray the stirring epic of the birth and growth of chemical engineering in America and the events that in a mere twenty-five years have transformed it from a formless conglomerate of chemistry and engineering into the crystalline structure of a new profession, recognized today as a definite branch of engineering.

The volume opens with an article on research in the industry by Arthur D. Little and a very readable résumé of progress in the acid and heavy chemical industry by Henry Howard. Chapters on solvents and petroleum refining, the electrochemical and electrometallurgical industry, the paper, coal, sugar, plastics, and lime industry, rubber, paints and varnishes, soaps and glycerin are all handled by authorities in their particular fields. A good chapter on the statistics of the industry and one on chemical engineering education closes the volume. References to sources are frequent, and the make-up and editorial work are such that the book will be valuable not alone as a statement of twenty-five years' development but as indication of trends toward the future. It may be recommended to the engineer whose interest may lie in this or cognate lines as there is hardly a field of engineering which is not touched in some measure by the chemical engineering industry.

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

Books Received in the Library

APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH IN RADIO RESEARCH. By R. A. Watson Watt, J. F. Herd, and L. H. Bainbridge-Bell. Department of Scientific & Industrial Research, London; obtainable from British Library of Information, New York, 1933. Cloth, 6 × 10 in., 290 pp., illus., diagrams, charts, tables, $2.55. The authors of this volume have been pioneers in the application of the cathode-ray oscillograph to the problems of radio research, and as its field of application has widened, there has been increasing inquiry for information concerning the technique of their methods. This report gives detailed information about the design and construction of the apparatus developed at the British Radio Research Station, and is intended for others engaged in work along similar lines. The book aims to be an introductory practical handbook upon the technique of frequency investigation with the oscillograph.

BUSINESS UNDER THE RECOVERY ACT. By L. Valenstein and E. B. Weiss. McGraw-Hill Book Co. (Whittlesey House), New York & London, 1933. Cloth, 5 × 8 in., 314 pp., $2.50. The question here considered is the effect which the National Recovery Act will have upon the passage of goods from the manufacturer to the ultimate consumer. The book discusses merchandising, selling, and advertising under the new conditions, with special consideration of ultimate, rather than immediate effects.

FLUGLEHRE, Vorträge über Theorie und Berechnung der Flugzeuge in Elementarer Darstellung. By R. von Mises. Fourth edition. Julius Springer, Berlin, 1933. Cloth, 6 × 9 in., 400 pp., charts, diagrams, tables, 15.50 rm. An elementary text upon the theory and design of airplanes, intended for students unable to handle higher mathematics. The book is based upon courses given to German military aviators during the War, and since at the universities of Dresden and Berlin. The volume is an excellent introduction to the subject.

INDUSTRIAL ELECTRICAL MEASURING INSTRUMENTS. By K. Edgcumbe and F. E. J. Ockenden. Isaac Pitman & Sons, London & New York, 1933. Cloth, 6 × 9 in., 553 pp., illus., diagrams, charts, tables, $7.50. This is a treatise upon the design, construction, and use of the many forms of instruments now available, written for the practical engineer. A comprehensive account of modern types of instruments for all purposes is given, with unusually full discussion of matters of design and construction. This edition is practically a new work, having been entirely rewritten and considerably enlarged, with marked improvement in contents and presentation.

INTERNAL-COMBUSTION ENGINES, Theory and Design. By V. L. Maleev. McGraw-Hill Book Co., New York & London, 1933. Cloth, 6 × 9 in., 386 pp., diagrams, charts, tables, $4. The principles involved

in the design and operation of internal-combustion engines are presented in combination with detailed instruction in methods of designing. The book is intended for use as a college text and by engineers and designers.

LABOR RELATIONS UNDER THE RECOVERY ACT. By O. Tead and H. C. Metcalf. McGraw-Hill Book Co. (Whittlesey House), New York & London, 1933. Cloth, 5 × 8 in., 259 pp., $2. This book aims to supply practical guidance to those interested in methods of organized dealing with employees in industries which are under the provisions of the National Recovery Act. The possibilities of employee representation and of company unions and labor unions are discussed in the light of the experience of the authors in labor and personnel work.

LES MÉTHODES D'ÉTUDE DES ALLIAGES MÉTALLIQUES. By L. Guillet. Second edition. Dunod, Paris, 1933. Cloth, 6 × 10 in., 859 pp., illus., diagrams, charts, tables, 203 frs. This book is wide in scope, discussing the physical, chemical, and mechanical properties of alloys. The latest methods and apparatus are described with sufficient fullness for practical purposes and useful lists of references accompany each topic. This edition has been rewritten and includes such topics as thermo-electricity, control of plating, shock and torsion tests, and abrasion tests, which were scarcely mentioned in the previous edition.

OFFENTLICHE HEIZKRAFTWERKE UND ELEKTRIZITÄTSWIRTSCHAFT IN STÄDTEN. By E. Schulz. Julius Springer, Berlin, 1933. Cloth, 7 × 10 in., 209 pp., illus., diagrams, charts, maps, tables, 28.50 rm. The possibilities and advantages of combining district heating and electricity supply are set forth in detail in this work. The principles of heat and power distribution are discussed, existing district heating systems in Europe and America are described, and the design of new systems is considered. The volume brings a large amount of theoretical and practical data together in a concise form.

SCHIFFBAU (Ausgewählte Schweisskonstruktionen, No. 5). By Lottmann. V.D.I. Verlag, Berlin, 1933. Cloth, 8 × 12 in., 50 pp., illus., diagrams, charts, 9 rm. A collection of fifty plates of photographs and drawings illustrating applications of welding to shipbuilding. The examples are chosen from the practise at the principal German shipyards. Brief descriptive notes in English accompany each plate.

WHAT'S GOING ON

Election of A.S.M.E. Officers for 1934

THE result of the election of officers of the A.S.M.E. for 1934 is as follows:

Office	Nominee	Votes
President	PAUL DOTY	3505
Vice-Presidents	WILLIAM L. BATT	3534
	H. L. DOOLITTLE	3534
	ELY C. HUTCHINSON	3528
	ELLIOTT H. WHITLOCK	3524
Managers	JAMES A. HALL	3530
	ERNEST L. OHLE	3531
	JAMES M. TODD	3534

Biographical sketches of the nominees for office may be found on pages 523–526 of the August issue of MECHANICAL ENGINEERING.

A Warning From Washington

THE Treasury Department will look with much disfavor on those architects or engineers who retain legal counsel in Washington to aid them in securing professional contracts from the Department; in fact, it will be the disposition of the Department to eliminate such architects and engineers from consideration altogether. This announcement was recently made by Assistant Secretary of the Treasury Robert, who has requested the American Institute of Architects and American Engineering Council to make the attitude of his office widely known.

Early in the summer the Treasury Department learned that certain Washington lawyers had been soliciting engineers, architects, and others, interested in obtaining Government business, representing that to retain such counsel would enhance the opportunities of the engineers and architects to obtain desirable contracts. This activity has been particularly prevalent in Western states.

The Treasury Department has not made public the names of the lawyers who engaged in this practise, feeling that probably they did not realize (1) that their proposal was in itself a reflection on certain Government officials; (2) that representation of the nature lawyers would provide could not possibly have any bearing upon the selections made by the Treasury Department.

The Department desires to make its selections on the merits of each case alone. There is no disposition on the part of the Department to prosecute any of the parties concerned, but it does want it emphatically understood that such a practise will be outlawed.

E.C.P.D. First Annual Meeting

THE first Annual Meeting of the Engineers' Council for Professional Development (see MECHANICAL ENGINEERING, August, 1932, p. 567; September, 1932, pp. 633–634 and 648; and September, 1933, p. 574) was held in New York, October 10, 1933. The afternoon session was called to order by C. F. Hirshfeld, chairman pro tempore of the interim executive committee. Announcement was made of the approval of the Council's charter and rules of procedure by six of the seven governing bodies of the participating Societies in a brief report of the activities of the executive committee by its secretary pro tempore, C. E. Davies.

Reports of the four standing committees to carry on the program of the Council were presented, discussed, and referred with appropriate recommendations to the governing bodies of the participating societies.

The following officers were elected: C. F. Hirshfeld, chairman, C. E. Davies, secretary, and J. Vipond Davies, Donald F. Irvin, William E. Wickenden, Charles F. Scott, H. C. Parmelee, R. I. Rees, and D. B. Steinman, members of the executive committee.

Dinner was served at the Engineers' Club. About 50 members of the Council and invited guests were present, with Chairman Hirshfeld presiding. The address was delivered by Dr. Franklin J. Keller, Director of the National Educational Conference. C. E. Davies summarized the actions taken by the Council at its afternoon session and the reports of the standing committees. D. B. Steinman, D. S. Kimball, and Gano Dunn spoke of the significance of the occasion and the opportunity for the Council that lay ahead. C. F. Hirshfeld solicited the sincere cooperation of all engineers in advancing the program of the Council.

On pages 692 and 693 of this issue, will be found comments on the Council, and a brief résumé of the reports of the standing committees.

Boiler Feedwater Committee Issues Report

IMPROVED methods for the determination of carbonates, hydroxides, and phosphates in boiler waters have been developed by a subcommittee of the Joint Research Committee on Boiler Feedwater Studies, which is sponsored by six of the leading engineering societies and associations in this country. These methods are described in three reports which have just been published for sale by the A.S.M.E. They represent the results of a research program conducted over the last two years at the University of Michigan under Prof. A. H. White, of the university, and C. H. Fellows, of the Detroit Edison Company, chairman of the subcommittee.

The purpose of publishing the methods at this time is to have them given practical trial and criticism by industry. From the results obtained, Committee D-19 on Analysis of Industrial Waters of the American Society for Testing Materials will prepare standard methods of water analysis suitable for referee and control purposes.

The investigation on carbonate determination was financed by the Detroit Edison Company and the results made available to the subcommittee. The other two programs were

financed by the joint research committee from a grant made by the Engineering Foundation.

The Joint Research Committee on Boiler Feedwater Studies, S. T. Powell, Chairman, was organized in 1925 to study methods of analysis and treatment of boiler feedwater in stationary and railroad practise. The Committee is sponsored by the American Boiler Manufacturers' Association, The American Railway Engineering Association, The American Water Works Association, the Edison Electric Institute, the American Society for Testing Materials, and The American Society of Mechanical Engineers.

The three reports have been bound together in one volume of approximately 100 pages. Copies may be obtained for $1.75 each from the A.S.M.E. Publication Sales Department, 29 West 39th Street, New York, N. Y. A further report of 100 pages has been prepared by the subcommittee and is entitled "The Determination of Sulphates in Boiler Waters." It contains a supplement indicating the possibility of using a direct titration method. Should sufficient requests be received for this report, it will be made available by the A.S.M.E. at not more than $2 a copy. Inquiries should be addressed to the Publications Sales Department.

Candidates for Membership in the A.S.M.E.

The application of each of the candidates listed below is to be voted on after November 25, 1933, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Members desiring further information, or having comments and objections, should write to the Secretary of the A.S.M.E. at once.

New Applications

Adams, Allan R., Blackwell, Okla.
Anderson, David W., Pasadena, Calif.
Bland, P. N., Vancouver, B. C., Canada
Burley, H. H., Brooklyn, N. Y.
Calkin, E. D., Portland, Oregon
Carson, Gordon B., South Euclid, Ohio
Chapman, Kenneth B., Providence, R. I.
Cushman, A. L., Concord, N. H.
de Crecy, Jacques, New York, N. Y.
Dorsey, Francis E., New Britain, Conn.
Duspiva, Leroy V., Brooklyn, N. Y.
Fitch, Kenneth S., Hollywood, Calif.
Handly, Marcellus G., Higginsville, Mo.
Hanhart, Ernest H., Jr., Baltimore, Md.
Holland, A. Dinsmore, Atlanta, Ga.
Jeannin, John F., Toledo, Ohio
Lebbad, Anthony A., Brooklyn, N. Y.
Lee, Gleason B., Providence, R. I.
Lott, Howard P., Idaho Falls, Idaho
Manifold, George O., Cleveland, Ohio
Marmont, E. Leonard, Gary, Ind.
McGarry, Francis J., Toledo, Ohio
McMahon, Charles M., Westboro, Mass.
Miller, Harold R., Wyoming, Ohio
Needham, H. Sydney, Passaic, N. J.
Peabody, E. C., Breckenridge, Colo.
Phillips, Lynn M., Flint, Mich.
Rao, B. Lakshmana, Vizianagaram City, South India
Reichel, Curt R., San Mateo, Calif.
Roberts, Cary Russell, Akron, Ohio
Rodgers, William M., Catonsville, Md.
Russell, J. J., Ft. Lee, N. J.
Rutledge, Alex., Verona, N. J.
Seewer, Ernest U., Prospect Park, Pa.
Spratt, H. P., London, England
Sprenger, Col. A. R., Montreal, Quebec, Canada
Strider, I. H., Clarksburg, W. Va.
Tann, Walter L., Jackson Heights, L. I.
Tullar, Irving, Elizabeth, N. J.
Vawter, W. Dale, Liberty, Kans.
Wallace, John H. G., Bremerton, Wash.
Woodfill, C. R., Clayton, Mo.

Change of Grading

Transfers from Associate-Member

Bliss, Zenas R., Providence, R. I.
Dell, Wm. H., Philadelphia, Pa.
Schultz, Oswald C., St. Joseph, Mich.
Sperry, Clarence E., New York, N. Y.
Thuerk, H. C., New York, N. Y.
Williams, Howard O., Minneapolis, Minn.

Transfers from Junior

Elwell, Richard, Cedarhurst, L. I.
Houghton, Wm. M., Lancaster, Pa.
Jobin, Francis J., Woodcliff, N. J.
Jones, J. Delbert, Tulsa, Okla.
Langner, F. W., Olean, N. Y.
Lewis, Richard C., Ansonia, Conn.
Mariana, Henry J., Bridgeport, Conn.
Mogensen, Allan H., New York, N. Y.
Marion, Frank I., Toledo, Ohio
Rogers, Donald A., Hopewell, Va.
Rohrhurst, Wm., Bound Brook, N. J.
Sager, Norbert W., McGill, Nevada
Schubert, Frank J., Lynbrook, L. I.
Smith, J. F. Downie, Cambridge, Mass.

Actions Taken by A.S.M.E. Executive Committee

At the September 22 meeting of the Executive Committee of the A.S.M.E. Council the following actions of general interest were taken:

Following a discussion of the economic importance of the stimulation of the industries engaged in the manufacture of capital goods in any effective program of national recovery, in which it was pointed out that mechanical engineers are largely employed in such industries and therefore immediately affected, the Committee voted to appoint a committee to formulate and execute without expense to the Society and as early as possible, a program which might include (*a*) a study of the basic economic facts involved; (*b*) the close cooperation of the American Engineering Council; (*c*) the stimulation of a country-wide discussion of the subject through meetings of the Sections; (*d*) the cooperation of all local engineering and industrial groups; and (*e*) adequate publicity.

President Potter was authorized to appoint a committee of junior members to study the participation of junior members in the activities of the Society. The committee was requested to report at the Council Meeting in December.

Mention was made last month (Mechanical Engineering, p. 628) of an NRA code for the professional-engineering division of the construction industry. The Executive Committee voted to endorse the code.

In connection with discussions growing out of the code, differences in practise of consulting engineers and manufacturers had been raised, and as the factors involved are of great importance to mechanical engineers, it was voted to appoint a committee to prepare a manual of practise for mechanical-engineering design, construction, and installation.

Secretary Rice was authorized to sign the President's Unemployment Agreement, thus putting the A.S.M.E. headquarters staff under the NRA.

Junior Division of A.S.M.E. Metropolitan Section, Organized

First among the Eastern sections to organize its junior members, the Metropolitan Section (New York City) of The American Society of Mechanical Engineers formally authorized a group of some fifty of the younger engineers to hold meetings and carry on business as a "Junior Division of the A.S.M.E. Metropolitan Section." This recognition, coming as the climax to six months of missionary work by two or three public-spirited junior members of the Society, was made known on September 26 at the first meeting of the season for the group at the Society's headquarters.

Plans for the coming year have already been formulated by the program and executive committees. These include inspection trips, informal lectures on broad engineering subjects, and discussion of problems relating to the young engineer.

Especially interesting to other sections contemplating a junior division, is the intention of the Program Committee to foster fellowship and understanding as well as engineering interest in fields outside of the individual's own activity by scheduling short talks by the members on their own particular problems.

At the meeting of September 26, officers for the coming year were announced and the enrolment of members was accomplished. After an introductory speech by the chairman, Mr. Hescheles, in which he stated that unless every member obtained greater value from the Society than he was called to contribute, the Executive Committee would admit complete failure, Mr. Richard Kutzleb, vice-chairman of the group, announced the formation of an employment committee and Mr. Vincent Zaffarano explained the requirements and procedure necessary to obtain a professional engineer's license.

The complete list of Junior officers follows: Chairman, Charles Hescheles; Vice-Chairman, Richard Kutzleb; Secretary, Albert Fox; Treasurer, Vincent Zaffarano; Committee Chairmen: Membership, Earnest Peverle; Nominating, Arthur Stern; Program, Ralph Behr; Publicity, Richard Warner; and Reception, Louis Brown.

A.S.M.E. ANNUAL MEETING

at New York, December 4 to 8

AS ANNOUNCED last month, the Annual Meeting of The American Society of Mechanical Engineers will be held at the Society's headquarters, 29 West 39th Street, New York, N. Y., December 4 to 8. A program as complete as conditions at time of going to press permitted will be found on the following pages.

The opening event will be the meeting of Council, on Monday morning, at which regional representatives of the local sections, the professional divisions, and standing and technical committees of the Society will be present. Reports of committees will be presented and discussed. The annual business meeting of the Society will take place Monday afternoon. At this session, after the reports of committees, there will be a discussion of changes in industry and engineering affecting the future policies of the Society. The views of members are desired for the guidance and assistance of the Committee on Policies and Budget which is engaged in the problem of examining critically the aims and purposes and restating them. It is also expected that some progress will be made in the program of the Society in the matter of increasing expenditures for capital goods.

Financial reasons again make it necessary to omit preprints of technical papers. Following the plan adopted for the Chicago meeting, a booklet of abstracts of technical papers, including the complete program of all technical and non-technical events and schedule of committee meetings, is being prepared for distribution to persons registering at the meeting. A few papers of general interest will be found in this issue of MECHANICAL ENGINEERING, and the December issue will contain others. Important addresses, and a few other papers of general interest, will appear in later issues. After the meeting, the Committee on Publications will make a selection of the technical papers presented in December, based on the recommendations of the Society's divisions and committees, for publication in the Transactions. Individual copies of the abstracts of technical papers published for distribution at the meeting are available on request for those who wish to prepare discussions. The abstracts contain approximately 1000 words and in most cases are sufficiently representative to serve as a basis for discussion.

The program, as printed in this issue, necessarily omits complete details of certain non-technical events and the schedule of committee meetings.

High points of the technical program will be recognized in the symposiums on heat transmission, planing versus milling, and water measurement; the papers on cooperation between industrial and public-utility power plants; and the management problems of industrial recovery. A joint session with the American Society of Refrigerating Engineers and the A.S.M.E. Process Industries Committee will be devoted to air conditioning.

The Henry Robinson Towne lecture on the relation of engineering and economics will be delivered by David Cushman Coyle, consulting engineer, of New York, whose book, "The Irrepressible Conflict: Business Vs. Finance," has been favorably commented on by economists and engineers, and whose article in the February issue of MECHANICAL ENGINEERING will be remembered by readers.

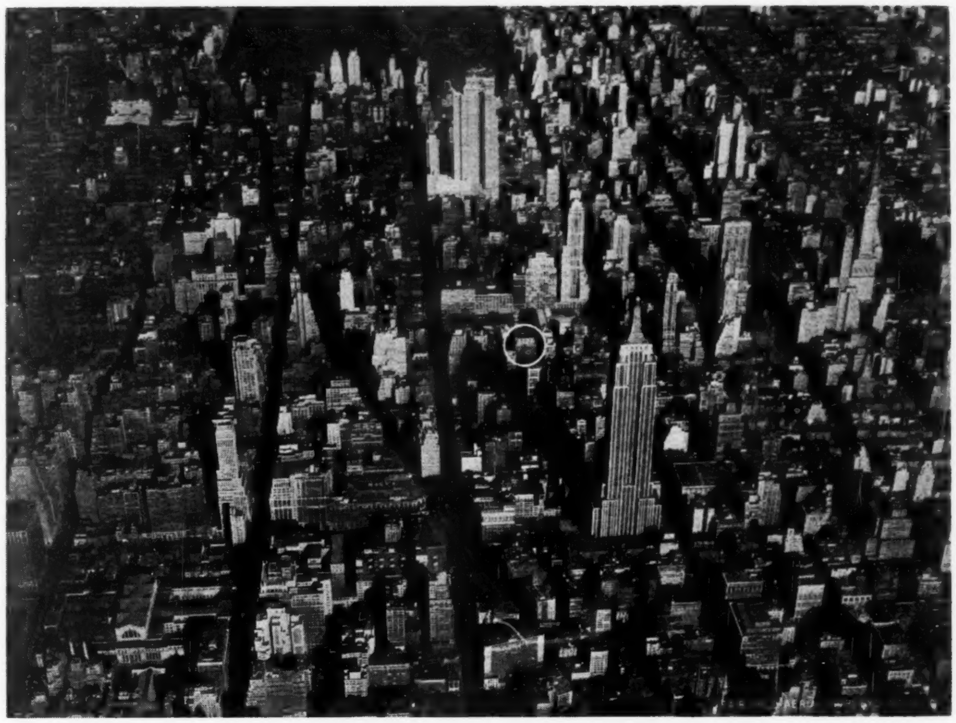
The Annual Dinner to new members is scheduled for Wednesday evening.

In commemoration of the fiftieth anniversary of the graduation from the institute of Frederick Winslow Taylor, Stevens Institute of Technology is planning a celebration at Hoboken, New Jersey, in which the A.S.M.E. and the Taylor Society will participate. The A.S.M.E. session on metal cutting, under the auspices of the Special Research Committee on Cutting of Metals, will be held in the auditorium of the Stevens Institute, in Hoboken, on Thursday morning in connection with this celebration. On Thursday afternoon there will be a special program on metal cutting at the Institute. Taylor memorabilia will be displayed at the library of the Institute. Other features of the celebration will be announced later.

REDUCED RAILROAD RATES

MEMBERS of The American Society of Mechanical Engineers planning to attend the 1933 Annual Meeting in New York, December 4 to 8, should secure certificates which will entitle them to return tickets at the rate of one-third the regular one-way fare. Certificates must be validated at the headquarters of the Society during the meeting. The return ticket must be purchased by December 12. Tickets so purchased will then be good for return passage to reach the original starting point within thirty days from the date of sale of the going ticket as shown on the certificate. It will, of course, be necessary to return by the going route. The one-third fare return rate will be available to members of The American Society of Mechanical Engineers, The American Society of Heating and Ventilating Engineers, American Welding Society, American Society of Testing Materials, American Society of Steel Treaters, The American Society of Refrigerating Engineers, The American Foundrymen's Association, and to members of the Institute of Aeronautic Sciences.

Attention is called to the fact that unless one hundred certificates are validated at headquarters, it will be impossible for any one to secure the reduced rate. Therefore, any one whose one-way fare to New York City is 75 cents or more should obtain a railroad certificate. From Eastern and Mid-West sections of the country tickets and certificates will be available from December 1 through December 7, while from the Pacific Coast certificates will probably be issued a few days prior to December 1.



LOOKING NORTH OVER MID-TOWN NEW YORK
(In the circle is the Engineering Societies Building where sessions of the A.S.M.E. Annual Meeting are held, and lying between the Empire State Building, in foreground, and Radio City, beyond which is Central Park.)

A.S.M.E. Program *for* 1933 ANNUAL MEETING

New York, N. Y., December 4-8

(Unless otherwise stated all events will be held at the Engineering Societies Building, 29 West 39th Street, New York, N. Y.)

MONDAY MORNING, DECEMBER 4

9:30 a.m. Council Meeting **Room 502**

(Local Sections, Professional Divisions, Standing and Technical Committees are invited to attend)

MONDAY AFTERNOON, DECEMBER 4

2:00 p.m. Business Meeting **Auditorium**

TUESDAY MORNING, DECEMBER 5

9:30 a.m. Conference of Local Sections Delegates **Room 1001**

9:30 a.m. Education and Training **Room 1101**

Auspices of Committee on Education and Training

Presiding Officer: General R. I. Rees, Mem. A.S.M.E., Assistant Vice-President, American Telephone and Telegraph Co., New York, N. Y.

Recorder: John T. Faig, Chairman, A.S.M.E. Committee on Education and Training, President, Ohio Mechanics Institute, Cincinnati, Ohio.

1—Training Within Industry in the Eastern States
By Ovid W. Eshbach, American Telephone and Telegraph Co., New York, N. Y.

2—Training Within Industry in the South
By Theodore S. Johnson, Professor of Industry, North Carolina State College of Agriculture and Engineering, Raleigh, N. C.

9:30 a.m. **Heat Transfer—I** **Room 1501**

Auspices of Power and Petroleum Divisions

Presiding Officer: C. E. Lucke, Mem. A.S.M.E., Professor of Mechanical Engineering, Columbia University, New York, N. Y.

Recorder: T. H. Hamilton, Mem. A.S.M.E., Examining Engineer, Federal Public Works of New Jersey, Newark, N. J.

1—Rates of Heat Transfer to the Radiant-Heat Absorbing Section of Pipe Stills
By Charles E. McCullough, Engineer, Foster-Wheeler Co., New York, N. Y.

2—Heat-Transfer Rates on Condensing, Reboiling, and Miscellaneous Heat-Exchange Services
By Max Higgin, Texas Co., New York, N. Y.

Galloway, N. Y.

THE EMPIRE STATE BUILDING, NEW YORK CITY

3—Application of Fouling Factors in the Design of Heat Exchangers

By E. N. SEIDER, Engineer, Foster-Wheeler Co., New York, N. Y.

4—The Accuracy of the Cleanliness Factor for Surface Condensers

By P. H. HARDIE, Assoc-Mem. A.S.M.E., Test Engineer, Brooklyn Edison Co., Brooklyn, N. Y., and W. S. COOPER, Assoc-Mem. A.S.M.E., Assistant Engineer, Brooklyn Edison Co., Brooklyn, N. Y.

9:30 a.m. Fuels Auditorium

Auspices of Fuels Division

Presiding Officer: Ely C. Hutchinson, Mem. A.S.M.E., President, Edge Moor Iron Co., Edge Moor, Del.

Recorder: W. G. Christy, Secretary, A.S.M.E. Fuels Division, Department of Smoke Regulation, Hudson County, New Jersey.

1—Progress Report No. 3 of the A.S.M.E. Special Research Committee on Removal of Ash as Molten Slag From Powdered-Coal Furnaces

By PERCY NICHOLLS, Mem. A.S.M.E., Supervisory Engineer, Fuels Section, U. S. Bureau of Mines, Experiment Station, Pittsburgh, Pa.

2—Burning Characteristics of Pulverized Fuels and Radiation From Their Flames

By R. A. SHERMAN, Chairman, A.S.M.E. Fuels Division, Fuel Engineer, Battelle Memorial Institute, Columbus, Ohio.

3—Progress in Fuel Engineering

9:30 a.m. Machine Design, Materials Handling Room 903

Auspices of Machine Shop Practice Division

Presiding Officer: B. P. Graves, Chairman, A.S.M.E. Machine Shop Practice Division, Brown & Sharpe Manufacturing Co., Providence, R. I.

Recorder: James A. Hall, Mem. A.S.M.E., Professor of Mechanical Engineering, Brown University, Providence, R. I.

1—Why Has the Machine Designer Failed to Consider Motion Study?

By ALLAN H. MOGENSEN, Jun. A.S.M.E., Consulting Editor, *Factory Management and Maintenance*, New York, N. Y.

2—Appearance in Design

By JOSEPH SINEL, Industrial Designer, New York, N. Y.

3—Progress in Materials Handling (presented by title)

9:30 a.m. Railroad—I Room 501

Auspices of Railroad Division

Presiding Officer: C. B. Peck, Vice-Chairman, A.S.M.E. Railroad Division, Associate Editor, *Railway Age*, New York, N. Y.

Recorder: Marion B. Richardson, Secretary, A.S.M.E. Railroad Division, Livingston, N. J.

1—Locomotive Counterbalancing

By LAWFORD H. FRY, Mem. A.S.M.E., Railway Engineer, Edgewater Steel Co., Pittsburgh, Pa.

2—Research and Development of Light-Weight High-Speed Passenger Trains

By E. E. ADAMS, Vice-President, Pullman Co., Chicago, Ill.

9:30 a.m. Water Measurement Symposium Room 502

Auspices of Hydraulic Division

Presiding Officer: Lewis F. Moody, Mem. A.S.M.E., Professor of Hydraulic Engineering, Princeton University, Princeton, N. J.

Recorder: K. W. Beattie, Research Assistant, Baldwin-Southwark Corporation, Philadelphia, Pa.

1—Analysis of the Gibson Method of Water Measurement

By DR. D. THOMA, Mem. A.S.M.E., Technische Hochschule, Munich, Germany.

2—Experimental and Practical Experience of the Gibson Method of Water Measurement

By NORMAN R. GIBSON, Mem. A.S.M.E., Vice-President and Chief Engineer, Niagara-Hudson Power Corporation, Buffalo, N. Y.

3—The Photo-Flow Method of Water Measurement

By WILLIAM MUNROE WHITE, Mem. A.S.M.E., Manager and Chief Engineer, Hydraulic Department, Allis-Chalmers Mfg. Co., and W. J. RHEINGANZ, Test Engineer, Hydraulic Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

4—How Water Flows in a Pipe Line

By CHARLES M. ALLEN, Mem. A.S.M.E., Professor of Hydraulic Engineering, Worcester Polytechnic Institute, Worcester, Mass.

5—Research Experiments on the Behavior of Current Meters in Flowing Water

By S. LOGAN KERR, Assoc-Mem. A.S.M.E., Research Engineer, Baldwin-Southwark Corporation, Philadelphia, Pa.

[Discussion led by JAMES J. TRAILL, Test Engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada]

TUESDAY AFTERNOON

2:00 p.m. Heat Transfer—II Room 1501

Auspices of Iron and Steel Division and A.S.S.T.

Presiding Officer: William Reuben Webster, Mem. A.S.M.E., Chairman of the Board, Bridgeport Brass Co., Bridgeport, Conn.

Recorder: William J. Jackson, Consulting Engineer, New York, N. Y.

1—The Effect of Angle of Emission on the Radiating Power of Various Oxidized Metal Surfaces

Report of Subcommittee D, Heat Transmission, National Research Council, R. E. Binkley, Lehigh University, Bethlehem, Pa.

2—Fuel-Fired Heat-Treating Furnace Transfer Rates

By M. Mawhinney, Assoc-Mem. A.S.M.E., Electric Furnace Co., Salem, Ohio. (A.S.S.T. paper.)

3—Transfer of Heat in Electric Furnaces

By R. D. Van Nostrand, Industrial Heating Engineering Dept., General Electric Co., Schenectady, N. Y. (A.S.S.T. paper.)

4—Quenching Media Heat-Transfer Rates

By Howard Scott, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. (A.S.S.T. paper.)

5—Discussion on Operating Data on Heat Transfer in Iron and Steel Plants

By Republic Steel Corp., Carnegie Steel Co., Bethlehem Steel Co., Arthur G. McKee Co., and H. A. Brassert Co.

2:00 p.m. Materials Handling and Process Room 1101

Auspices of Materials Handling Division and Process Industries Committee

Presiding Officer: C. P. Tolman, Mem. A.S.M.E., Consulting Engineer, New York, N. Y.

Recorder: T. R. Olive, Jun. A.S.M.E., Assistant Editor, *Chemical and Metallurgical Engineering*, McGraw-Hill Co., New York, N. Y.

1—Survey of Drying Methods

By C. W. Thomas, Mem. A.S.M.E., Consulting Engineer, New York, N. Y., and Arnold Weisselberg, Jun. A.S.M.E., Mechanical Engineer, New York, N. Y.

2—Redler Method of Bulk Conveying of Chemicals

By Nixon W. Elmer, Mem. A.S.M.E., Redler Engineer, Stephenson-Adamson Mfg. Co., Ridgeway, Aurora, Ill.

3—Engineering in the Brewery Industry

By Victor Buhr, Vice-President, Equity Construction Co., New York, N. Y.

2:00 p.m. Milling Vs. Planing Auditorium

Auspices of Machine Shop Practice Division

Presiding Officer: Joseph W. Roe, Mem. A.S.M.E., Professor of Industrial Engineering, New York University, New York, N. Y.

Recorder: R. E. W. Harrison, Secretary, A.S.M.E. Machine Shop Practice Division.

1—Planing Versus Milling

By A. C. Danekind, Mechanical Engineer, Manufacturing General Department, General Electric Co., Schenectady, N. Y.

2—The Case for Milling

By R. E. W. Harrison, Mem. A.S.M.E., Secretary, A.S.M.E. Machine Shop Practice Division.

3—The Case for Planing

By Forrest Cardullo, Mem. A.S.M.E., Chief Engineer, G. A. Gray Co., Cincinnati, Ohio.

2:00 p.m. Applied Mechanics Room 903

Auspices of Applied Mechanics Division

Presiding Officer: G. B. Pegram, Mem. A.S.M.E., Professor of Physics, Columbia University, New York, N. Y.

Recorder: F. M. Lewis, Mem. A.S.M.E., Professor of Engineering, Webb Institute of Naval Architecture, New York, N. Y.

1—Stress Concentration Factors for Tension Bars With Holes and Notches

By A. M. Wahl, Assoc-Mem. A.S.M.E., Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., and R. Beeuwkes, Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

2—Stress Concentration at Fillets

By E. E. Weibel, Department of Engineering Mechanics, University of Michigan, Ann Arbor, Mich.

3—A Membrane Analogy Supplementing Photoelasticity

By J. G. McGivern and H. L. Supper, Engineering School, Harvard University, Cambridge, Mass.

4—Progress in Applied Mechanics (presented by title)

2:00 p.m. Water Measurement Room 502

Auspices of Hydraulic Division

Presiding Officer: D. J. McCormack, Chairman, A.S.M.E. Hydraulic Division; S. Morgan Smith Co., York, Pa.

Recorder: I. Gutmann, Engineering Index, A.S.M.E., New York, N. Y.

Galloway, N. Y.

RIVERSIDE CHURCH, ON RIVERSIDE DRIVE, NEW YORK CITY

Galloway, N. Y.

THE GEORGE WASHINGTON BRIDGE ACROSS THE HUDSON RIVER CONNECTING NEW JERSEY WITH NEW YORK CITY

1—Observations of the Use of Current Meters for Precise Flow Measurements

By Dr. A. Ott, Mathematics Institute, Kempton, Germany.

2—Water Measurement With Current Meters in Hydraulic-Turbine Plants

By Dr. Hahn, Director, J. M. Voith, Heidenheim, Germany.

3—Water Gaging for Low-Head Units of High Capacity

By M. J. Mousson, Safe Harbor Water Power Corp., Baltimore, Md.

4—The Use of Current Meters for Precise Measurement of Flow

By Floyd A. Nagler, Professor of Hydraulic Engineering, Director of Iowa Institute of Hydraulic Research, Iowa City, Iowa.

5—Current-Meter Testing

By John C. Hoyt, Hydraulic Engineer, U. S. Geological Survey, Washington, D. C.

6—Factors Affecting Accuracy of Current-Meter Measurement

By Carl Rohwer, Associate Irrigation Engineer, U. S. Department of Agriculture, Fort Collins, Colo.

7—Current-Meter Testing at Rock Island Hydroelectric Development

By T. B. Parker, Wellesley Hills, Mass.

2:00 p.m. Railroad—II Room 501

Auspices of Railroad Division

Presiding Officer: L. K. Sillcox, Chairman, A.S.M.E. Railroad Division; New York Air Brake Co., New York, N. Y.

Recorder: Marion B. Richardson, Secretary, A.S.M.E. Railroad Division, Livingston, N. J.

1—Research and Development of Steel for Railway Equipment

2—Extent to Which Locomotive Standardization Is Possible

By H. H. Vaughan, Consulting Engineer, Montreal, Quebec.

3—Developments in Railroad Research

4—Progress in Railroad Engineering (presented by title)

4:30 p.m. Henry Robinson Towne Lecture Auditorium

Presiding Officer: Dr. Harvey N. Davis, President, Stevens Institute of Technology, Hoboken, N. J.

High Productivity and the Distribution Problem

By David Cushman Coyle, Consulting Engineer, New York, N. Y.

TUESDAY EVENING, DECEMBER 5

8:30 p.m. President's Night **Auditorium and Fifth Floor**

WEDNESDAY MORNING, DECEMBER 6

9:30 a.m. Industrial Power Auditorium

Auspices of Power Division

Presiding Officer: Robert H. Fernald, Mem. A.S.M.E., Dean of the Towne Scientific School, University of Pennsylvania, Philadelphia, Pa.

Recorder: J. M. Brentlinger, Mem. A.S.M.E., E. I. du Pont de Nemours & Co., Wilmington, Del.

1—Cooperation Between Industrial and Public-Utility Companies in the Generation of Steam and Electric Energy

By H. D. Harkins, Mem. A.S.M.E., Industrial Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del.

2—Some Broader Aspects of Planning for Industrial Steam and Supply Projects

By Vern E. Alden, Assoc-Mem. A.S.M.E., Power Engineer, Stone & Webster Engineering Corporation, Boston, Mass.

3—Progress in Power Engineering

9:30 a.m. Lubrication Research Room 502

Auspices of Lubrication Research Committee and Applied Mechanics Division

Presiding Officer: George B. Karelitz, Mem. A.S.M.E., Associate Professor of Mechanical Engineering, Columbia University, New York, N. Y.

Recorder: Harvey N. Konheim, Assoc-Mem. A.S.M.E., Consulting Engineer, New York, N. Y.

1—Heat Effects in Lubricating Films

By Albert Kingsbury, Mem. A.S.M.E., President, Kingsbury Machine Works, Philadelphia, Pa.

2—Oil-Film Whirl—A Non-Whirling Bearing

By Burt L. Newkirk, Mem. A.S.M.E., Engineer, General Electric Co., Schenectady, N. Y., and Lloyd P. Grobel, General Electric Co., Schenectady, N. Y.

9:30 a.m. Management Research Room 501

Auspices of Management Division

Presiding Officer: F. E. Raymond, Chairman, A.S.M.E. Management Division; Professor, Massachusetts Institute of Technology.

Recorder: W. M. Kushnick, Secretary, A.S.M.E. Management Division; Anchor Cap and Closure Corp., Long Island City, N. Y.

1—What Psychology Can Contribute to Industrial Stability

By R. Likert, Associate Professor of Psychology, New York University, New York, N. Y.

2—Some Human Problems in the Management of Technological Change—Preliminary Report of Labor Research in Regard to Textile Stretch-Out

By Elliott Dunlap Smith, Master, Saybrook College, Yale University, New Haven, Conn.

3—Relation of Safety to Management

By an authority in the field of industrial relations

4—Progress in Management (presented by title)

9:30 a.m. Fluid Meters Room 903

Auspices of Special Research Committee on Fluid Meters

Presiding Officer: R. J. S. Pigott, Chairman, A.S.M.E. Fluid Meters Committee; Gulf Production & Pipe Line Companies, Pittsburgh, Pa.

Recorder: I. Gutmann, Engineering Index, A.S.M.E., New York, N. Y.

1—Orifice Discharge Coefficients for Viscous Liquids

By R. E. Sprenkle, Assoc-Mem. A.S.M.E., Mechanical Engineer, Bailey Meter Co., Cleveland, Ohio, and G. L. Tuve, Assoc-Mem. A.S.M.E., Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

2—Determination of Discharge Coefficients of Sharp-Edged Orifices in Pipes of From 1 In. to 14 In. in Diameter

By S. R. Beitler, Jun. A.S.M.E., Assistant Professor of Mechanical Engineering, Ohio State University, Columbus, Ohio.

9:30 a.m. Textiles Room 1101

Auspices of Textile Division

Presiding Officer: Paul A. Merriam, Chairman, A.S.M.E. Textile Division; Consulting Engineer, Providence, R. I.

Recorder: M. A. Golrick, Jr., Secretary, A.S.M.E. Textile Division; Dutchess Bleachery, Inc., Wappingers Falls, N. Y.

1—Fulling Woolen and Worsted Fabrics

By H. C. Riggs, President, Riggs & Lombard, Lowell, Mass.

2—Depreciation of Textile Machinery

By A. W. Benoit, Mem. A.S.M.E., Associate Engineer, Chas. T. Main, Inc., Boston, Mass.

3—Progress in Textile Engineering

12:30 p.m. Textile Luncheon $1.00 Fraternities Club, 38th St. and Madison Ave., New York, N. Y.

1—The Use of Lastex in Textiles

By Percy Adamson, Adamson Brothers, New York, N. Y.

WEDNESDAY AFTERNOON, DECEMBER 10

2:00 p.m. Lubrication Engineering Room 501

Auspices of Petroleum Division

Presiding Officer: H. J. Masson, Secretary, A.S.M.E. Petroleum Division; Professor, New York University, New York, N. Y.

Recorder: Walter C. Thee, Secretary, Lubricating Engineering Committee, A.S.M.E.; Motor Repair Shops, Fort Hancock, Sandy Hook.

1—Railroad Service Testing of Journal Lubrication and Lubricants

By Robert Job, Vice-President, Milton Hersey Co., Ltd.; Consulting Chemist, Canadian National Railways, Montreal, Canada.

Oil and Gas Power
9:30 a.m. Room 1501

Auspices of Oil and Gas Power Division

Presiding Officer: E. J. Kates, Secretary, A.S.M.E. Oil and Gas Power Division; Consulting Engineer, New York, N. Y.

Recorder: Julius Kuttner, Mem. A.S.M.E., Consulting Engineer, New York, N. Y.

1—The Present Status of the Humphrey Gas Pump for Pumping Water by Displacement

By F. du P. Thomson, Mem. A.S.M.E., Elkton, Md.

2—Improving Diesel-Engine Operation by the Selection of a Proper Exhaust-Pipe Length

By Kyle Carlin Whitefield, Jun. A.S.M.E., University of Wisconsin, Madison, Wis.

3—Progress in Oil and Gas Power Engineering

Galloway, N. Y.

NEW YORK CITY AT NIGHT

2—Investigation of Properties Necessary for All-Year Car Oil

By CLIFFORD M. LARSON, Mem. A.S.M.E., Supervisory Engineer, Sinclair Refining Co., New York, N. Y.

3—Errors and Corrections in Viscosity Measurement

By WALTER J. ALBERSHEIM, Consulting Engineer, New York, N. Y., CLIFFORD M. LARSON, Mem. A.S.M.E., Supervisory Engineer, Sinclair Refining Co., New York, N. Y., and HARVEY KONHEIM, Assoc-Mem., Consulting Engineer, New York, N. Y.

4—Progress in Petroleum Engineering

By C. H. BROMLEY, Mem. A.S.M.E., Lubrication Engineering Committee; Pure Oil Co., New York, N. Y.

2:00 p.m. Steam Tables Research Room 903

Auspices of Special Research Committee

Presiding Officer: A. M. Greene, Jr., Mem. A.S.M.E., Dean, Mechanical Engineering, Princeton University, Princeton, N. J.

Recorder: R. G. Napoli, Junior Engineer, United Electric Light & Power Co., New York, N. Y.

1—Reports of Special Research Committee on Thermal Properties of Steam

2:00 p.m. Foundry Room 502

Auspices of Machine Shop Practice Division and American Foundrymen's Association

Presiding Officer: Wilbur J. Peets, Mem. A.S.M.E., Singer Mfg. Co., Elizabethport, N. J.

Recorder: R. E. Kennedy, Secretary, A.S.M.E. Committee on Foundry Practice; Secretary, American Foundrymen's Association, Chicago, Ill.

1—The Meaning of the Transverse Test of Cast Iron to the Designing Engineer

By JAMES T. MACKENZIE, Metallurgist, American Cast Iron Pipe Co., Birmingham, Ala.

2—Welded Joints

By EVERETT CHAPMAN, Mem. A.S.M.E., Vice-President, Director Engineering Research, Lukenweld, Inc., Coatesville, Pa.

2:00 p.m. Management Auditorium

Presiding Officer: John R. Shea, Vice-Chairman, A.S.M.E. Management Division; Assistant Engineer, Western Electric Co., Kearny, N. J.

Recorder: George W. Kelsey, Mem. A.S.M.E., G. W. Kelsey & Co., Engineers, New York, N. Y.

Problems of Industrial Recovery—Internal Problems—I:

1—The Plant and Its Equipment

2—The Product

By WILLARD E. FREELAND, Assoc-Mem. A.S.M.E., Vice-President, Freeland, Bates & Lawrence, Inc., Boston, Mass.

3—Policies in Marketing

By PAUL T. CHERINGTON, Business Consultant, New York, N. Y.

2:00 p.m. Heat-Transfer Symposium Room 1501

Auspices of American Society of Heating and Ventilating Engineers, American Society of Refrigerating Engineers, and The American Society of Mechanical Engineers

Presiding Officer: John H. Sengstaken, Assoc-Mem. A.S.M.E., Mechanical Engineer, Superheater Co., New York, N. Y.

Recorder: Mario Gianinni, New York University, New York, N. Y.

1—Heat-Transfer Rates in Refrigerating and Air-Cooling Apparatus

By W. J. KING and W. L. KNAUS, General Electric Co., Schenectady, N. Y.

2—Heat-Transfer Rates in Heating and Ventilating or Air-Conditioning Practise

By F. C. HOUGHTEN, Mem. A.S.M.E., Director, Research Laboratory, American Society of Heating and Ventilating Engineers, Pittsburgh, Pa.

3—The Heat Transfer in Economizers and Air Heaters

By HENRY KREISINGER, Mem. A.S.M.E., Consulting Engineer, Combustion Engineering Co., New York, N. Y.

4—The Heat Transfer in Mercury Systems

By W. T. MOORE, Jun. A.S.M.E., Test Engineer, Babcock & Wilcox Co., New York, N. Y.

2:00 p.m. Creep of Metals Room 1101

Auspices of Plasticity Committee of Applied Mechanics Division

Presiding Officer: A. Nadai, Chairman, A.S.M.E. Plasticity Committee; Westinghouse Research Laboratories, East Pittsburgh, Pa.

Recorder: Carlos de Zafra, Mem. A.S.M.E., New York University, New York, N. Y.

1—Report of Joint High-Temperature Committee of A.S.M.E. and A.S.T.M. on 18-8 Alloy, Containing Also Fatigue Tests at Elevated Temperatures

By H. C. CROSS, Battelle Memorial Institute, Columbus, Ohio.

2—Working Stresses for High-Temperature Service

By P. G. MCVETTY, Mem. A.S.M.E., Mechanical Engineer, Westinghouse Research Laboratory, East Pittsburgh, Pa.

3—The Elastic Properties of Steel at High Temperatures

By GUY VERSÉ, University of Michigan, Ann Arbor, Mich.

6:30 p.m. Annual Dinner to New Members

[Seating at the banquet will take place promptly at 6:45 p.m., and service will begin promptly at 7:00 o'clock.]

THURSDAY MORNING, DECEMBER 7

9:30 a.m. Organization Meeting of Committee on Local Sections **Room 1001**

9:30 a.m. Airship Session Room 1501

Auspices of Aeronautic Division

Presiding Officer: J. C. Hunsaker, Mem. A.S.M.E., Head of Mechanical Engineering Department, Massachusetts Institute of Technology, Cambridge, Mass., and President of Institute of Aeronautic Sciences.

Recorder: Jerome Lederer, Chairman, A.S.M.E. Committee on Aircraft Safety and Inspection; Chief Engineer, Aeronautic Insurance Underwriters, New York, N. Y.

1—Improving Airship Performance

By GARLAND FULTON, Commander, Bureau of Aeronautics, Navy Department, Washington, D. C.

2—Some Design Aspects of the Rigid Airship

By KARL ARNSTEIN, Mem. A.S.M.E., Vice-President in Charge of Engineering, Goodyear-Zeppelin Corporation, Akron, Ohio.

3—Progress in Aeronautical Engineering

9:30 a.m. **Central Power Station** **Auditorium**

Auspices of A.S.M.E. Power Division

Presiding Officer: Edwin B. Ricketts, Mem. A.S.M.E., Research Engineer, New York Edison Co., New York, N. Y.

Recorder: A. E. Grunert, Mem. A.S.M.E., Commonwealth Edison Co., Chicago, Ill.

1—The Thermal Performance of the Detroit Turbine Using Steam at 1000 F

By F. O. ELLENWOOD, Mem. A.S.M.E., Professor of Heat Power Engineering, Cornell University, Ithaca, N. Y., and W. A. CARTER, Assoc-Mem. A.S.M.E., Technical Engineer of Power Plants, Detroit Edison Co., Detroit, Mich.

2—High-Temperature Steam Experience at Detroit

By P. W. THOMPSON, Mem. A.S.M.E., Chief Engineer of Power Plants, Detroit Edison Co., Detroit, Mich.

9:30 a.m. **Stress Analysis** **Room 502**

Auspices of Applied Mechanics Division

Presiding Officer: Charles Joseph Tilden, Professor, Chairman of Department of Engineering Mechanics, Yale University, New Haven, Conn.

Recorder: E. O. Waters, Assoc-Mem. A.S.M.E., Associate Professor of Mechanical Engineering, Yale University, New Haven, Conn.

1—Design and Calculation of Steam-Turbine Disk Wheels

By J. MALKIN, Westinghouse Elec. and Mfg. Co., South Philadelphia Works, Philadelphia, Pa.

2—Some New Experiments on Thin-Sheet Construction

By F. J. BRIDGET, A. B. VOSSELLER, and C. C. JEROME, California Institute of Technology, Pasadena, Calif. (*Post-Graduate Work.*)

3—Bending of Circular Plates With Large Deflection

By STEWART WAY, University of Michigan, Ann Arbor, Mich.

10:00 a.m. **Metal Cutting** **Stevens Institute**

Auspices of Special Research Committee on Cutting of Metals

Presiding Officer: F. C. Spencer, Chairman, A.S.M.E., Cutting of Metals Committee; Assistant Superintendent, Manufacturing Development, Western Electric Co., Kearny, N. J.

Recorder: Coleman Sellers, Mem. A.S.M.E., Executive Engineer, William Sellers Co., Inc., Philadelphia, Pa.

1—Performance of Cutting Fluids When Sawing Off Various Metals

(Progress Report No. 5 of Subcomittee on Cutting Fluids)

By O. W. BOSTON, Mem. A.S.M.E., Professor, and C. E. KRAUS, Jun. A.S.M.E., University of Michigan, Ann Arbor, Mich.

2—X-Ray Determination of Depth of Cold Working

By L. THOMASSEN, Assistant Professor of Chemical Engineering, and D. M. MCCUTCHEON, University of Michigan, Ann Arbor, Mich.

[NOTE: This session will be followed in the afternoon at 2:00 P.M. by a Special Metal-Cutting Demonstration at Stevens Institute]

9:30 a.m. **Economics Session** **Room 501**

Auspices of Management Division

Presiding Officer: Roscoe C. Edlund, Managing Director, Association of American Soap and Glycerine Products, Inc., New York, N. Y.

Recorder: G. E. Hagemann, Mem. A.S.M.E., Editor, Alexander Hamilton Institute, New York, N. Y.

Problems of Industrial Recovery—External Problems—II:

1—Industrial Codes and Cooperation

Discussion opened by RALPH E. FLANDERS, Mem. A.S.M.E., President, Jones & Lamson Machine Co., Springfield, Vt.

9:30 a.m. **Iron and Steel** **Room 1101**

Auspices of Iron and Steel Division

Presiding Officer: A. J. Boynton, Chairman, A.S.M.E. Iron and Steel Division; H. A. Brassert Co., Chicago, Ill.

Recorder: J. H. Hitchcock, Secretary, A.S.M.E., Iron and Steel Division; Engineer, Morgan Construction Co., Worcester, Mass.

1—Investigating the Performance of Bearing Metals and the Wear on These Metals

By J. R. CONNELLY, Jun. A.S.M.E., Instructor of Mechanical Engineering, Lehigh University, Bethlehem, Pa.

2—Possibilities of Mechanical Control as Applied to Metallurgical Furnaces

By H. J. VELTEN, H. A. Brassert Co., Chicago, Ill.

3—Progress in Iron and Steel

4—Discussion on Foreign and American Progress in Manufacture of Sheets

By F. L. ESTEP, Mem. A.S.M.E., Consulting Engineer, Vice-President, Perin Engineering Co., New York, N. Y.

THURSDAY AFTERNOON, DECEMBER 7

2:00 p.m. **Central Station** **Auditorium**

Auspices of Power Division

Presiding Officer: Nevin E. Funk, Mem. A.S.M.E., Vice-President in Charge of Engineering, Philadelphia Electric Co., Philadelphia, Pa.

Recorder: A. E. Grunert, Mem. A.S.M.E., Research Engineer, Commonwealth Edison Co., Chicago, Ill.

1—Supersaturated Steam

By JOHN I. YELLOTT, JR., Jun. A.S.M.E., Instructor of Mechanical Engineering, University of Rochester, Rochester, N. Y.

2—Leaving Velocity and Exhaust Loss in Steam Turbines

By E. L. ROBINSON, Mem. A.S.M.E., Turbine Engineer, General Electric Co., Schenectady, N. Y.

3—Progress in Power Engineering (presented by title)

2:00 p.m. **Air Conditioning** **Room 501**

Joint Auspices of A.S.R.E. and A.S.M.E. Process Industries Committee

Presiding Officer: Clyde R. Place, Mem. A.S.M.E., Consulting Engineer, New York, N. Y.

Recorder: J. C. Hardigg, Mem. A.S.M.E., Consulting Engineer, New York, N. Y.

1—Psychrometric Investigations and Data

By DR. F. G. KEYES, Massachusetts Institute of Technology, Cambridge, Mass.

2—Physiological Side of Air Conditioning

By R. R. SAYRES, Medical Officer in Charge, Bureau of Industrial Hygiene and Sanitation, U. S. Public Health Service, Washington, D. C.

3—Noise Elimination and Air Motion

By C. B. GRAVES, Manager, Air Condition Division, Campbell Metal Window Corporation, New York, N. Y.

2:00 p.m. **Mechanical Springs** **Room 1101**

Auspices of A.S.M.E. Special Research Committee on Mechanical Springs

Presiding Officer: J. R. Townsend, Chairman, A.S.M.E. Mechanical Springs Committee; Member of Technical Staff, Bell Telephone Laboratories, New York, N. Y.

Recorder: William R. Bryans, Mem. A.S.M.E., Assistant Dean, New York University, New York, N. Y.

1—Analysis of Stress in a Helical Spring of Circular Wire
By H. C. Perkins, Professor, Cornell University, Ithaca, N. Y.

2—Elastic Behavior and Creep
By M. F. Sayre, Mem. A.S.M.E., Professor of Mechanical Engineering, Union College, Schenectady, N. Y.

3—Fatigue and Mechanical Properties of Spring Material
By D. J. McAdam, Jr., Metallurgist, U. S. Bureau of Standards, Washington, D. C.

4—An Investigation of Eccentricity of Load in Helical Springs
By J. B. Reynolds, Professor of Mathematics and Theoretical Mechanics, and J. F. Houser, Jr., Mem. A.S.M.E., Lehigh University, Bethlehem, Pa.

2:00 p.m. **Boiler Feedwater Session** **Room 1501**

Auspices of Boiler Feedwater Studies Committee

Presiding Officer: S. T. Powell, Chairman, A.S.M.E. Boiler Feedwater Studies Committee, Baltimore, Md.

Recorder: Arthur C. Coonradt, Assoc-Mem. A.S.M.E., New York University, New York, N. Y.

1—Progress Report on the Determination of Dissolved Oxygen in Boiler Feedwater
By C. H. Fellowes, Chairman, Subcommittee on Standardization of Water Analyses, Detroit Edison Co., Detroit, Mich.

2—The Solubility of Sodium Sulphate in Boiler-Water Salines as Related to the Prevention of Embrittlement
By Everett P. Partridge, Supervising Engineer, and W. C. Schroeder, Research Chemical Engineer, Non-Metallic Minerals Experiment Station, U. S. Bureau of Mines, New Brunswick, N. J. (Progress Report from the Research Study at the Bureau of Mines)

3—A New Boiler-Water Treatment for the United States Navy
By Lieut.-Comm. T. A. Solberg and Robert Carson Adams, Jr., U. S. Naval Experiment Station, Annapolis, Md. (*Contributions to the Committee's Activities.*)

4—Silicon, a Major Constituent of Boiler Scales in Western Oregon
By R. E. Summers, Jun. A.S.M.E., and C. S. Keevil, Professors, Oregon State Agricultural College, Corvallis, Ore. (*Contributions to the Committee's Activities.*)

2:00 p.m. **Engineering Education** **Room 502**

Auspices of Committee on Relations With Colleges

Presiding Officer: Donald B. Prentice, Mem. A.S.M.E., President, Rose Polytechnic Institute, Terre Haute, Ind.

Recorder: E. F. Church, Jr., Mem. A.S.M.E., Professor of Mechanical Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

1—What Industry Wants Our Engineering Students to Have in the Way of Economic Training
By Ralph E. Flanders, Mem. A.S.M.E., President, Jones & Lamson Machine Co., Springfield, Vt.

2:00 p.m. **Economics Session** **Room 903**

Auspices of Management Division

Discussion on Planned Industrial Economy (continued)—Opened by E. Dillon Smith, Columbia University

THURSDAY, DECEMBER 7, 1933

Frederick W. Taylor Celebration

Stevens Institute of Technology, Hoboken, N. J.

10:00 a.m.	Exhibits of Taylor Memorabilia (All Day)	**Library**
10:00 a.m.	A.S.M.E. Metal-Cutting Session	**Auditorium**
2:00 p.m.	Metal-Cutting Program	**Auditorium and Laboratory**
4:00 p.m.	Sketch—Episodes in Taylor's Life	**Auditorium**
6:00 p.m.	Supper	**Castle Stevens**
8:00 p.m.	Evening Program	**Auditorium**

FRIDAY MORNING, DECEMBER 8

9:30 a.m. Council Meeting **Room 1101**

Fairchild Aerial Surveys, Inc., N. Y

THE SKYSCRAPERS OF LOWER MANHATTAN